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Edited by

CARLETON REA and J. RAMSBOTTOM

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THE RUSTS AND SMUTS OF BERMUDA.

By Professors H. H. Whetzel and H. S. Jackson.

IDENTIFICATION of the parasitic fungi of a region cannot be satisfactorily prosecuted until its flowering plants and ferns have been collected and thoroughly studied. The publication in 1918 of the *Flora of Bermuda* by N. L. Britton gave us the first thorough and complete presentation of the flowering plant and fern flora of these islands.

A year's residence in Bermuda during 1921–2, in the employ of the Department of Agriculture of the colony, afforded the senior author the opportunity to initiate a somewhat extensive collection of the fungi of these islands. This was supplemented by a five weeks' collecting trip in company with F. J. Seaver, of the New York Botanical Garden, during the winter of 1926. It is hoped that succeeding years will offer further opportunities to continue the fungus explorations to the end that a more or less complete fungus flora of Bermuda may be compiled and published. Meanwhile it is proposed to publish critical papers on some of the more important groups of the fungi occurring in these islands, of which this is the first.

The earliest collection of fungi recorded from Bermuda appears to be that made by H. N. Mosley, Naturalist of the *Challenger* Expedition in 1873. M. J. Berkeley published two lists of Bermuda fungi based on Mosley's collections (1875, 1877) comprising a total of twenty-three species, among which was one smut and one rust. The first, listed as *Ustilago carbo* Tul., is not to be found in the Kew Herbarium, no host is given and so it cannot be identified. The second, *Uredo Vincetoxici* DC., said to be on oleander, proves to be on examination *Coleosporium Solidaginis* on leaves of *Solidago sempervirens*. A revised list based on the same collections was prepared by M. C. Cooke and published by Hemsley (1885). He enumerates twenty-four species. To the one smut and one rust above mentioned is added *Puccinia Lantanae* Farl.

The next collection of fungi from Bermuda of which we find a record was made by Captain H. A. Cummins* during the period December, 1896, to January, 1898. His specimens were identified by Geo. Massee and published by him in two lists (1898, 1899) in the *Kew Bulletin of Miscellaneous Information.*

* In a letter, August, 1927, to Miss E. M. Wakefield, Professor Cummins writes: "I arrived in Bermuda, December, 1896, and I left for England in January, 1898. I did not put in a full tour of army service there as I exchanged to serve in England. I collected specimens all the time I was there and had correspondence chiefly with George Massee."

A total of eight species are recorded of which one is a smut, *Ustilago Stenotaphri* described as a new species, and two are rusts, listed as *Uromyces striatus* and *Puccinia Virgaureae*. This last species is doubtless *Coleosporium Solidaginis*. The specimen is not now to be found in the Kew Herbarium. *Graphiola Phoenicis* is recorded as a rust. These specimens were deposited in the Kew Herbarium in London. During the years 1880 and 1881, W. G. Farlow made a few collections of fungi in Bermuda, among which were several rusts now to be found in the Harvard Herbarium at Cambridge, Massachusetts. Duplicates of most of these are also in the Arthur Rust Herbarium at Lafayette, Indiana. These are reported by Arthur in the *North American Flora*.

Following this the most extensive collection of fungi from these islands was made by B. O. Dodge during the summer of 1911. His specimens were deposited in the herbarium of the New York Botanical Garden and the herbarium of Columbia University, New York City. No rusts or smuts collected by Dodge have been found by the writers in these herbaria. According to Seaver (1916, p. 504), Dodge collected *Ustilago Zeae*. We have not been able to locate the specimen. No collector before or since appears to have taken the corn smut in Bermuda.

During the years from 1905 to 1913 inclusive S. Brown, N. L. Britton and other collectors from the New York Botanical Garden made incidental collections of fungi while studying the flowering plants of the islands. Among these were a few rusts and smuts which were deposited in the cryptogamic herbarium of the Garden.

During November and December, 1912, F. J. Seaver made a rather extensive collection of fungi in Bermuda among which were a few rusts. These species were listed by Seaver (1916, pp. 509–10) along with others which he found in the herbarium in the New York Botanical Garden. There is in this list but one smut, *Ustilago Zeae* already referred to. Nine rusts are reported: *Uromyces proeminens, Uromyces Medicaginis, Puccinia Lantanae, Puccinia Dichondrae, Puccinia Cladii, Puccinia Polygoni-amphibii, Puccinia purpurea, Tranzschelia punctata* and *Gymnosporangium bermudianum*. Duplicates of all rusts collected by Seaver and his colleagues were sent to J. C. Arthur for determination and these are deposited in the Arthur Rust Herbarium.

This appears to represent all the collections of fungi from Bermuda prior to those made by the senior writer during 1921–2. Although an attempt was made to take specimens of all forms of fungi which came to our hands during this year, a special search was made for rusts and smuts on all flowering plants

both wild and cultivated in all parts of the islands. Lawrence Ogilvie, who came to the Bermuda Department of Agriculture as plant pathologist in 1923, has continued the search for rusts and smuts and has added several species not previously taken in the islands. During January and February, 1926, the senior writer again visited Bermuda in company with F. J. Seaver for further work on the fungus flora of the islands. Together with Mr. Ogilvie the three of us added approximately three hundred specimens of fungi to the collections made during 1921–2. Among these were a few additional rusts.

In preparing this paper on the rusts and smuts of Bermuda we have attempted to locate and examine as far as possible all specimens and published accounts of rusts and smuts known from Bermuda. We believe the list to be substantially complete and correct. The plants of these islands have been so thoroughly combed for these parasites that few additional species are likely to be found except as new introductions occur.

The smut fungi represented in Bermuda comprise nine species distributed through five genera. Of these species six are here reported from Bermuda for the first time, *U. Zeae*, *U. affinis* and *Entyloma fuscum* alone having been heretofore recorded from the islands. Three new hosts for smut fungi have been discovered: *Rhynchospora distans* and *Rhynchospora stipitata* for *Cintractia Montagnei* and *Chaetochloa geniculata* for *Sphacelotheca pamparum*. None of the smuts collected in Bermuda are endemic. Most if not all represent introductions from various quarters of the globe. The most interesting from this point of view are *Entyloma Meliloti* from Australia, *Entyloma fuscum* from Europe and *Sphacelotheca pamparum*, a South American or Mexican species.

The rust fungi represented in the Bermuda flora comprise forty-nine species distributed in twelve genera including the form genus *Uredo*. Of these species twenty-four are here reported for the first time from these islands. Our survey has thus nearly doubled the species heretofore known from Bermuda. But one of these rusts, *Uredo nominata* on the endemic host *Sisyrinchium bermudianum*, is peculiar to Bermuda. The others are for the most part species common along the Atlantic seaboard of the United States or in the West Indies. Some are evidently importations from Europe. What is probably an importation from South America and the only rust in this list new to the *North American Flora*, is *Uredo Parthenii* on the common weed *Parthenium hysterophorus*. Fern rusts of the genus *Uredinopsis* are well represented by four species. The largest number of species are of the genus *Puccinia*. It is remarkable that although many of the rusts of Bermuda are heteroecious not a single

aecial form has been found there, if we except the Roestelia stage of the autoecious *Gymnosporangium bermudianum*. It is worthy of note that collections from Bermuda have yielded the telial stage of at least three species known elsewhere only in the uredinial form: *Puccinia Cladii* reported by Seaver (1916, p. 504), *Puccinia Dichromenae* and *Puccinia superior*. Descriptions of the telial forms of the last two prepared by the junior author are presented in this paper. Both are on hosts new for the respective rusts.

New hosts for seven rusts have been discovered during our explorations: for *Coleosporium Ipomoeae, Ipomoea sagittata*; for *Coleosporium Solidaginis, Leptilon pusillum*; for *Puccinia Dichromenae, Dichromena colorata*; for *Puccinia superior, Fimbrystilis castanea*; for *Puccinia tubulosa, Oplismenus hirtellus*; for *Uromyces Scirpi, Scirpus Olneyi* and for *Uromyces perigynius, Carex albolutescens*.

In addition to the usual taxonomic data and critical notes included in similar lists of fungi, the authors have included brief notes on the field aspect of each species as a guide to amateur collectors. No attempt has been made to give a complete synonomy of each species listed, but rather such of the names as will be most useful to other workers. As far as possible all specimens examined or known to exist in various herbaria have been cited except in the case of those in the Arthur Rust Herbarium which are, we believe, duplicates in all cases of specimens cited from other herbaria. Where the name of the collector is omitted it is to be understood that these are specimens collected by the senior writer. Unless otherwise indicated specimens cited are a part of the exsiccatum, Bermuda Fungi, deposited in the herbarium of the Department of Plant Pathology at Cornell University, Ithaca, N.Y. Most of the species reported prior to this paper are represented by specimens in the New York Botanical Garden Cryptogamic Herbarium (cited as **N.Y.B.G. Herb.**).

The identification of the specimens upon which the records herein recorded are largely based has been the labour of the junior author, who is also responsible for the nomenclatorial features of the paper. The field notes and comments have been prepared by the senior author from his notes and observations made while collecting in Bermuda.

The writers are under obligations to several of their colleagues for assistance of one sort or another in the preparation of this list. N. L. Britton and others at the New York Botanical Garden have identified the host plants. J. C. Arthur has given critical advice and assistance with the rusts. G. P. Clinton has rendered similar service with the smuts. F. J. Seaver, Curator

of the Cryptogamic collections of the N.Y. Botanical Garden, has placed every facility there at our disposal. Lawrence Ogilvie of the Bermuda Department of Agriculture has contributed a number of interesting rusts to the list and was especially helpful during our collecting trip to Bermuda in 1926. Both he and F. D. Kern of Pennsylvania State College have read the manuscript and have made numerous important corrections and additions thereto. The director at Kew has kindly loaned certain specimens for examination, and Miss E. M. Wakefield of that institution has been most helpful with information regarding early Bermuda collections in the herbarium there. The senior writer acknowledges a special debt of gratitude to the Bermuda Department of Agriculture and to Director E. A. McCallan in particular for the opportunity to collect fungi afforded during a whole year in the islands in 1921–2. To all of these and others who have in any way aided in making this list of the rusts and smuts of Bermuda complete and accurate we extend our hearty thanks.

USTILAGINALES.

Cintractia Montagnei (Tul.) Magn. *Abh. Bot. Ver. Prov. Brand.* xxxvii (1896), 79.

Ustilago Montagnei Tul. *Ann. Sci. Nat.* III, vii (1847), 88.

On Cyperaceae:

Rhynchospora distans (Michx.) Vahl. Devonshire Marsh, Aug. 8, 1921, **26.**

Rhynchospora stipitata Chapm. Devonshire Marsh, March 14, 1922, 61; **N.Y.B.G. Herb.** Britton, Aug.–Sept. 1905, 335; **Farlow Herb.** Moore, Devonshire, July 18, 1905 (?); **U. Cal. Herb.** Wm. and Clara B. Setchell, Devonshire Marsh, June 6, 1921.

This smut produces its spore-masses in place of the ovaries of these sedges. It was found in great abundance in Devonshire Marsh in August, 1921. It was however in a rather old condition indicating that it develops in the spring or early summer. The species is a very common one, having a wide distribution in North and South America as well as in Europe and Africa on other species of *Rhynchospora.*

While this appears to be the first published record of this smut in Bermuda, it was collected there as early as 1905 by N. L. Britton on *R. stipitata* and on what is probably the same host by A. H. Moore. A duplicate of Moore's specimen in Clinton's collection at New Haven, Conn., gives *Rhynchospora* sp. as the host. It is apparently *R. stipitata.* A duplicate of the Setchell specimen is also in Clinton's collection.

Both of the above species of *Rhynchospora* appear to be new hosts for this smut. That this smut is not confined to these hosts in Bermuda is indicated by a specimen in Clinton's collection on *R. stipitata* from Miami, Fla., collected by H. C. Cowles, Nov. 30, 1906.

Entyloma fuscum Schroet. *Beitr. Biol. Pfl.* II (1877), 373.

On Papaveraceae:

Papaver Rhoeas L. Clifton, Paget, Feb. 19, 1922, 58.

This smut is an uncommon species in America, having been reported only on cultivated poppies from Maine and New Brunswick. It is however apparently common in Europe.

It appeared in a garden, causing a spotting and yellowing of the leaves of seedling Shirley poppies (Whetzel, 1923, p. 29). Col. Harvey, C.R.E., had imported several lots of seeds from England, in one sowing of which this smut developed severely, spreading to other sowings near by. It apparently came in with the seed. The spots are circular, dark coloured, dead areas about $\frac{1}{4}$ inch in diameter. A white mouldy growth covers the under surface of the lesion and the dead tissue is filled with the globose dark brown chlamydospores.

Entyloma Meliloti McAlpine. *Smuts of Australia*, p. 195. 1910.

On Fabaceae:

Melilotus indica (L.) All. King's Point, Somerset, Mar. 8, 1922, 59.

So far as we know this is the first record of this species in America. The smut causes necrotic lesions in the leaves. The under surface of the lesion about the minute dead centre is coated with a white mouldy growth giving the under side of affected leaves a whitish spotted appearance. This is due to an abundant production of conidia. The conidia were not described by McAlpine. They are colourless, cylindric, slightly bent, 2–2·5 by 28–32μ. The species appears to be common on this host everywhere in the islands during the spring months; known otherwise only from Australia.

Sorosporium Syntherismae (Peck) Farl. Farlow and Seymour, *Host Index N. Am. Fungi*, p. 152. 1891.

Ustilago Syntherismae Pk. *Ann. Rept. N.Y. State Mus.* XXVII (1875), 103.

Sorosporium Cenchri P. Henn. *Hedwigia*, XXXV (1896), 221.

On Poaceae:

Cenchrus tribuloides L. Elba Beach, June, 1921, 9.

This smut occurs in Bermuda on the sea-shore burr grass. The entire head is invested by the spore mass even before it

begins to emerge from the upper leaf sheath. The large spiny seeds are replaced by a mass of powdery dark brown spores and the involucres and rachis are deformed and fibrous. The diseased heads protrude but slightly from the upper leaf sheath so that the smut is easily overlooked. The fungus appears to be systemic, like *Ustilago affinis* attacking *Stenotaphrum*. All the tillers of the plant are smutted, and are much dwarfed and multiplied in numbers, giving the affected plants a dense tufted aspect as compared with the more open spreading habit of the healthy plants about them.

This American species is common through the eastern United States on various species of *Cenchrus* and *Panicum*. It is also known from Mexico and South America.

Sphacelotheca pamparum (Speg.) Clinton. *Journ. Myc.* viii (1902), 140.

Ustilago Setariae "Niessl"?, Speg. *Anal. Soc. Ci. Argent.* x (1880), 5. Not *Ustilago Setariae* Niessl.

Ustilago pamparum Speg. *Anal. Soc. Ci. Argent.* xvii (1884), 89.

Ustilago Kolaczekii Kühn, Rab.-Wint. *Fungi Eur.* 3401. 1886.

On Poaceae:

Chaetochloa geniculata (Lam.) Millsp. and Chase. Paget West, July 19, 1921, 10; Paget East, Jan. 14, 1926, 96.

This rather rare smut, originally described from Argentine, is also reported from Cuba, Mexico and Europe. This appears to be the first record of this smut on *Chaetochloa geniculata* though Clinton (letter Feb. 1, 1927) advises us of a specimen on this host collected by Holway, Jan. 13, 1920, in Chile. It is not to be confused with the more common *Ustilago neglecta* Niessl. which is apparently found only on *Chaetochloa glauca*.

This is a very common smut on perennial foxtail in Bermuda, occurring especially along road sides. Wherever it occurs, a large percentage of the heads are affected. The smut is abundant in January and July and apparently throughout the year. It is easily detected, as one rides along the road, from the dark dense aspect which it gives to affected heads. The spore mass replaces the kernel.

Ustilago affinis Ellis and Ev., Cockerell. *Bull. Torrey Club*, xx (1893), 297.

Ustilago Stenotaphri P. Henn. *Hedwigia*, xxxvii (1898), 293. Not *Ustilago Stenotaphri* of McAlpine.

Ustilago Stenotaphri Massee. *Kew Bull. Misc. Inf.* cliii (1899), 184.

On Poaceae:

Stenotaphrum secundatum (Walt.) Kuntze (*Stenotaphrum glabrum* Trin.). Southampton, Aug. 27, 1921, 38; **N.Y.B.G. Herb.** Britton, hills north of Hamilton, Aug.–Sept. 1905, 64; **Farlow Herb.** Farlow, Hamilton, Jan. 1881; **U. Cal. Herb.** Wm. and Clara B. Setchell, Hamilton Parish, June 6, 1921; **Kew Herb.** Cummins, St Georges (date?).

This is an exceedingly common smut throughout Bermuda on the common crabgrass. The seeds of the grass are replaced by the globose black spore masses of the fungus. The smut spores are developed before the inflorescence emerges from the leaf sheath so that the young heads appear with two rows of dark round smut boils, each covered with a thin grey membrane. This pellicle soon ruptures and the powdery spore mass sifts out on the wind. The parasite seems to be "systemic," *i.e.* the mycelium spreads throughout the entire plant, so that all the heads of an affected plant show smut. This smut is so common that mature seed of this grass is not produced in any quantity. The prostrate rooting habit of the grass however enables it to prosper in spite of this handicap, and as the fungus within causes no apparent injury other than a slight dwarfing of the plant and destruction of the seed, the fungus can hardly be considered a menace to this best lawn grass of Bermuda. The smut is so abundant in Bermuda that many of the inhabitants regard it as normal to the crabgrass. They think the spore masses are the pollen (see Whetzel, 1922, p. 47, and 1923, p. 29).

This much-named smut (see Clinton, *N. Am. Fl.* VII (1906), 9), besides occurring in Bermuda, has been reported from Porto Rico, Vieques, Jamaica, Mexico, South America and South Africa. Massee's type specimen (in Kew Herb.) was collected in Bermuda near St Georges by Capt. H. A. Cummins. It appears to be common throughout the tropics wherever *S. secundatum* occurs.

Ustilago Avenae (Pers.) Jens. *Charb. Céréales*, p. 4. 1889.

On Poaceae:

Avena sativa L. Ogilvie, Tuckerstown, June 19, 1926, **215**; Ogilvie, Pembroke roadside, June 18, 1927, **378**; Ogilvie, Roadside, Paget, June 20, 1927, **379**.

This smut probably occurs rather frequently in volunteer oat plants as does the covered smut (*Ustilago levis*) though it has been collected only recently by Mr. Ogilvie. As oats are not grown as a crop in these islands both smut species owe their occasional presence here to importation on grain used for animal provender. The loose smut is distinguished from the covered smut by the more dusty character of the spore mass and the

minutely warted character of the spore wall, that of *Ustilago levis* being smooth. This loose smut is common wherever oats are grown.

Ustilago levis (Kell. and Sw.) Magn. *Abh. Bot. Ver. Prov. Brand.* xxxvii (1896), 69.
Ustilago avenae levis Kell. and Sw. *Ann. Rept. Kan. Agr. Exp. Sta.* ii (1890), 259.
On Poaceae:
Avena sativa L. Along roadside, Warwick, May 14, 1922, **72**.

The covered smut occurs occasionally on volunteer oats along the roadsides or about manure piles. This smut occurs on oats throughout the range of this cereal.

Ustilago carbo Tul.

A record of a smut under this name collected in Bermuda, June, 1873, by the *Challenger* Expedition is made by Berkeley (1875, p. 48) and again by Hemsley (1885, p. 103). It was collected by Mosley, botanist of the expedition. The specimen according to Hemsley bears no memorandum as to host, etc. It is apparently no longer to be found in the herbarium at Kew where it was presumably deposited (letter from E. M. Wakefield, Feb. 2, 1927).

Ustilago Zeae (Beckm.) Unger. *Einfl. Bodens*, p. 211. 1836.
Lycoperdon Zeae Beckm. *Hannov. Mag.* vi (1768), 1330.
On Poaceae:
Zea Mays L.

This parasite causes the common corn smut. It forms large boil-like swellings on the stalks and other organs of both the sweet and field corn. It is usually common on maize wherever grown.

This fungus was collected in Bermuda according to Seaver (1916, p. 504) by Dodge in August, 1911. No specimen of the Dodge collection is to be found in the Herbarium of the New York Botanical Garden. Although constantly on the alert for it during the summer of 1921, not a single case was observed by the senior author. It certainly does not appear to be common or destructive in these islands.

UREDINALES.

Cerotelium desmium (Berk. and Br.) Arth. *N. Am. Fl.* vii (1925), 698.
Aecidium desmium Berk. and Br. *Journ. Linn. Soc.* xiv (1875), 95.
Uredo Gossypii Lagerh. *Journ. Myc.* vii (1891), 48.

Kuehneola Gossypii Arth. *N. Am. Fl.* VII (1912), 187.
Cerotelium Gossypii Arth. *Bull. Torrey Club*, XLIV (1917), 510.

On MALVACEAE:

Gossypium herbaceum L. Ogilvie and Whetzel, Devonshire garden, Jan. 18, 1926, **91**.

Ogilvie had taken this rust in the same garden in November, 1924.

Although cotton plants are occasionally met with as ornamentals in Bermuda yards and gardens, a single collection only of this rust so common on cotton species in the tropics is known to the writers from these islands. This rust is readily recognised by its minute brown uredinial sori scattered over the leaf, especially on the under side. This rust is common throughout the tropics on species of *Gossypium*.

CEROTELIUM FICI (Cast.) Arth. *Bull. Torrey Club*, XLIV (1917), 509.
Uredo Fici Cast.; Desmaz. *Fl. Crypt.* (Fasc. 34), **1662**. 1848.
Physopella Fici Arth. *Résult. Sci. Congr. Bot. Vienna*, p. 338. 1906.
Kuehneola Fici Butler. *Ann. Myc.* XII (1914), 76.

On ARTOCARPACEAE:

Ficus Carica L. June, 1921, 5.

This rust, early reported by Harris (1910, 1911) as destructive to fig culture in Bermuda, is found throughout the islands on the fig which grows not only in gardens, but as volunteer trees in abandoned quarries and along walls. The earliest record of the occurrence of this rust in Bermuda is that by Bishop (1902, p. 10). It is very destructive to the foliage, causing it to turn brown, curl and fall off. The uredinia alone occur appearing as minute yellow dusty specks over the under surface of the leaves. The leaf tissue about each sorus is killed and turning black gives the leaf a flecked aspect from above. The tree constantly puts out new foliage as the affected leaves fall. Following each rain there is a new infection and defoliation, so that the trees are alternately full of leaves and then all but leafless. This disease, as Harris (1910) has already pointed out, undoubtedly is responsible for the dropping of the fruits when half grown, as a result of which ripe figs are now seldom seen in the islands (Whetzel, 1923, p. 29). Dusting just before rains with sulphur protects the foliage from the rust and insures the maturity of the fruit (Whetzel, 1922, p. 48).

In spite of its prevalence and striking injury this rust appears never to have been collected in Bermuda before. It occurs throughout the tropics on various species of *Ficus*.

Coleosporium Ipomoeae (Schw.) Burr. *Bull. Ill. Lab. Nat. Hist.* II (1885), 217.

Uredo Ipomoeae Schw. *Schr. Nat. Ges. Leipzig*, I (1822), 70.

On Convolvulaceae:

Ipomoea sagittata Lam. Warwick Marshes, July 19, 1921, 13.

This rust forms bright yellow uredinial sori scattered over the under side of the leaves of arrow-leaved morning glory which is very abundant in Warwick swamp, climbing up the sedges and rushes along the margin of the marsh. This rust, which occurs on many other species of *Ipomoea*, including the sweet potato, is found throughout the United States and the West Indies. *Ipomoea sagittata* appears to be a new host record for this species. The rust has not been found in Bermuda on any of the other *Ipomoea* species, of which there are eight. This suggests biologic specialisation of races within this species.

Coleosporium Solidaginis (Schw.) Thüm. *Bull. Torrey Club*, VI (1878), 216.

Uredo Solidaginis Schw. *Schr. Nat. Ges. Leipzig*, I (1822), 70.

Peridermium acicolum Underw. and Earle. *Bull. Torrey Club*, XXIII (1896), 400.

Peridermium montanum Arth. and Kern. *Bull. Torrey Club*, XXXIII (1906), 413.

Coleosporium Asterum Sydow. *Ann. Myc.* XII (1914), 109.

On Carduaceae:

Solidago sempervirens L. Elba Beach, June, 1921, 7; **N.Y.B.G. Herb.** Britton and Brown, Sept. 9, 1912, 986.

Leptilon pusillum (Nutt) Britton. Ogilvie, Pembroke Marsh, June, 1927, 376.

Massee (1899, p. 185) records under the name *Puccinia Virgaureae* Libert what is undoubtedly this rust from a collection by Captain H. A. Cummins from near St Georges. No Bermuda specimen bearing this name is now to be found at Kew. There is a specimen of this rust from Bermuda in the Kew Herbarium under the name *Uredo Vincetoxici*. (See note under this name below.)

The bright yellow uredinia of this rust are almost always to be found on the upper side of the lower leaves of the one species of golden rod occurring in Bermuda. The lower leaves of the golden rod are prematurely killed by the rust. They turn brown, shrivel and hang down about the stem giving the plants a very dilapidated appearance during spring and summer. The rust though present on the leaves seems to be less injurious during the winter months. The discovery of this rust on *Leptilon pusillum* adds a new host to the long list of plants on which this

fungus occurs. The aecial stage of this rust occurs on leaves of pines throughout eastern United States. As none of its *Pinus* host species are to be found in Bermuda it is carried along by urediniospores produced continuously on the golden rod. This rust does not appear to have been before reported from Bermuda although it is common on this and other species of *Solidago*, *Aster* and related plants in the United States.

Gymnosporangium bermudianum (Farl.) Earle. Seymour and Earle, *Econ. Fungi*, p. 249. 1892.
Aecidium bermudianum Farl. *Bot. Gaz.* XII (1887), 206.
Tremella bermudiana Arth. *Proc. Ind. Acad. Sci.* 1900, p. 136. 1901.

On Juniperaceae:

Juniperus bermudiana L. Mar. 1922, 60; **Farlow Herb.** Farlow, Feb. 1881 and another July, 1881.

This fungus forms rather small globose, reddish brown galls on the twigs of the native cedar. Just when these galls first appear was not determined. When first found in November many of them were already nearly one-fourth of an inch in diameter. However, tiny galls less than one-eighth of an inch in diameter were common in January at which time no evidence of the sori could be seen even on the largest galls. These galls seem to originate, at least in many cases, not in a single leaf but at the tip of a branch. Many galls show a crown of several dead leaf tips, giving it a "horned" aspect.

The fungus seems to be confined to individual trees, the others near by with interlacing branches being entirely free. Both male and female trees harbour the galls.

Aecia were collected for the first time about Feb. 15. This rust occurs also on species of juniper in the Bahamas and southern United States.

Kuehneola Uredinis (Link) Arth. *N. Am. Fl.* VII (1912), 186.
Oidium Uredinis Link. *Willd. Sp. Pl.* VI[1] (1824), 123.
Chrysomyxa albida Kühn. *Bot. Centr.* XVI (1883), 154.
Phragmidium albidum Lagerh. *Mitth. Bad. Bot. Ver.* (1888), p. 44.
Coleosporium Rubi Ellis and Holway. Saccardo, *Syll. Fung.* VII (1888), 759.
Kuehneola albida Magn. *Bot. Centr.* LXXIV (1898), 169.

On Rosaceae:

Rubus trivialis Michx. Garden in Paget, June 27, 1926, **88.**

The southern dewberry (*Rubus trivialis*) is not uncommon in gardens in Bermuda, and although there was a large clump at the

Agricultural Station in 1921, the rust was never found until 1926 when it appeared in the garden of Mr. Lynk in Paget. The plant had been imported recently from southern United States. The powdery yellow sori of the uredinial stage were very abundant on the leaves and young canes. It was causing severe yellowing and defoliation.

This rust is common on species of *Rubus* throughout eastern United States and occurs sparingly on the Pacific coast. It also occurs in Europe.

Prospodium appendiculatum (Wint.) Arth. *Journ. Myc.* XIII (1907), 31.

Puccinia appendiculata Wint. *Flora*, LXVII (1844), 262.

On Bignoniaceae:

Tecoma stans (L.) Juss. (*Stenolobium stans* Seem.) Tralee, Paget, June 22, 1922, 53.

This rust is rather widely distributed on the above host throughout tropical America. We found it (uredinial stage only) on an isolated young bush in a shady place at Tralee in Paget. The minute yellowish uredinia on the underside of the leaves are easily overlooked.

Puccinia Antirrhini Dietel and Holway. Dietel, *Hedwigia*, XXXVI (1897), 298.

Puccinia Cordylanthi Blasdale. *Univ. Cal. Publ. Bot.* VII (1918), 134.

On Scrophulariaceae:

Antirrhinum majus L. Shelley Bay, May 4, 1922, 67.

This rust, so destructive to snapdragons in America, was first observed by the senior author in Bermuda, in two gardens during the spring of 1922 (Whetzel, 1923, p. 29. The date "1921" there given is an error). The following year it became destructive in several places in the islands (Whetzel, 1924, p. 48). It has since become generally epiphytotic and very destructive (Ogilvie, 1925, p. 41, and 1926, p. 61). The evidence would seem to indicate that it had not occurred previous to 1922 in these islands. It is reported from Bermuda by Arthur in *North American Flora*, 1922, from specimens sent him by the senior author that year. Uredinia and telia only are known.

Puccinia Cannae (Wint.) P. Henn. *Hedwigia*, XLI (1902), 105.

Uredo Cannae Wint. *Hedwigia*, XXIII (1884), 172.

Dicaeoma (?) ***Cannae*** Arth. *N. Am. Fl.* VII (1920), 380.

On Cannaceae:

Canna indica L. O. Degener, Paget, Sept. 7, 1921, 36; Knutsford Paget, Mar. 14, 1922, 69.

Canna glauca L. Agr. Exp. Sta. Grounds, Nov. 2, 1921, and Feb. 21, 1922, 42.

This is the common rust of cannas (Whetzel, 1923, p. 29). The older lower leaves are usually affected. Where abundant sori are produced the leaves soon turn brown and die. It is easily recognised by its bright yellow powdery uredinia scattered over the lower surface of the leaves. It is very common in Bermuda on both the red and the yellow cannas (*Canna indica* and *Canna glauca*). During February, 1922, the telia were found abundantly on the leaves of the same plants as those from which the uredinia were collected in November on *Canna glauca*. It also occurs abundantly in Cuba, Trinidad, Santo Domingo, Jamaica and Porto Rico, as well as in Central and South America.

Puccinia Cladii Ellis and Tracy; Ellis and Everhart. *Bull. Torrey Club*, XXII (1895), 61.

Dicaeoma Cladii Arth. *Résult. Sci. Congr. Bot. Vienne*, p. 344. 1906.

On Cyperaceae:

Mariscus jamaicensis (Crantz) Britton. Pembroke Swamp, Aug. 8, 1921, **22**; Paget Marsh, Aug. 14, 1921, **30**; **N.Y.B.G. Herb.** Britton, Brown and Seaver, Nov. 29–Dec. 14, 1912, **1509**.

This rust is very common in the marshes on the leaves of the saw grass or prickly sedge, forming its small brown uredinia on the lower side of the large saw-edged leaves.

It was first described from south-eastern United States where it is common on this host. It is also known from Porto Rico. Seaver (1916, p. 504) first collected this rust in Bermuda in 1912. Seaver's statement that his collection was on a new host is based on a letter from J. C. Arthur and is an error.

Puccinia Cenchri Dietel and Holway. *Bot. Gaz.* XXIV (1897), 28.

Dicaeoma Cenchri Arth. *Résult. Sci. Congr. Bot. Vienne*, p. 334. 1906.

Uredo cencrophila Speg. *Anal. Mus. Nac. Buenos Aires*, XIX (1909), 316.

On Poaceae:

Cenchrus echinatus L. St David's Island, Dec. 21, 1921, **50**.

Although the host is very common the rust was found in Bermuda but once. Both uredinia and telia are present in this collection. This rust is very widespread in the West Indies and tropical America.

Puccinia Chrysanthemi Roze. *Bull. Soc. Myc. Fr.* XVII (1900), 92.
Puccinia Chrysanthemi-chinensis P. Henn. *Hedwigia Beibl.* XL (1901), 26.
Dicaeoma Chrysanthemi Arth. *Proc. Ind. Acad. Sci.* 1903 (1904), 147.
On Carduaceae:
Chrysanthemum morifolium Ramat.

The only records of the occurrence of this rust in Bermuda are two brief notes by L. Ogilvie (1925, p. 41, and 1926, p. 61) in his annual reports of 1924 and 1925 as plant pathologist for the Department of Agriculture. He merely records its occurrence. No specimens of this rust from Bermuda have been seen by the authors.

Puccinia Cichorii (DC.) Bell, Kickx. *Fl. Crypt. Fland.* II (1867), 65.
Uredo Cichorii DC. *Fl.* VI (1815), 74.
Bullaria Hieracii Arth. *Résult. Sci. Congr. Bot. Vienne*, p. 346. 1906.
On Cichoriaceae:
Cichorium Intybus L. Paget, July, 1921, 11.

Chicory, which is a common roadside weed here, is usually attacked by this rust which is especially abundant during the summer. It forms minute dark pustules scattered over the underside of the leaves. These are the uredinia. Telia were not found. This rust is reported from Bermuda by Arthur in *N. Am. Flora*, 1922. It is world-wide in its distribution.

Puccinia coronata Corda. *Ic. Fung.* I (1837), 6.
Dicaeoma Rhamni Kuntze. *Rev. Gen.* III³ (1898), 470.
On Poaceae:
Avena sativa L. Clifton, Devonshire, Apr. 16, 1922, 63; Paget East, May 23, 1922, 85; Warwick, Jan. 31, 1926, 99; Ogilvie, Pembroke Marsh West, June 21, 1927, 380.

Volunteer oats on which this rust is often very abundant are very common along roadways, in potato fields and about barns during the winter. Although uredinia only are usually present, the black telial crusts are to be found in limited quantity. This is a common rust on oats wherever it is grown.

Puccinia Cynodontis Lecroix, Desmaz. *Pl. Crypt.* II (1859), 655.
Aecidium Plantaginis Ces. *Erb. Critt. Ital.* 247. 1859.
Dicaeoma Cynodontis Kuntze. *Rev. Gen.* III³ (1898), 468.
On Poaceae:
Capriola dactylon (L.) Kuntze. Hamilton, July 25, 1921, 19.

This rust was taken by the senior writer but once on the common Bermuda grass or running grass. It may be much more common than this single collection would indicate as the sori are very minute and the effect of the fungus on the host is not marked. This rust is common on *Capriola dactylon* in tropical and subtropical countries throughout the world. The aecial form, known only from Europe and Japan, affects *Plantago* species.

Puccinia Dichondrae Mont.; C. Gay. *Fl. Chil.* VIII (1852), 46.

Micropuccinia Dichondrae Arth. and Jackson. *N. Am. Fl.* VII (1922), 556.

On Dichondraceae:

Dichondra carolinensis Michx. Paget Marsh, Nov. 13, 1921, 46; **N.Y.B.G. Herb.**, Brown, Harrington House, Feb. 11, 1908, 433; Brown, Britton and Seaver, Nov. 29–Dec. 14, 1912, 1491; Brown, Britton and Bisset, May 22–June 6, 1914, 2003.

This striking rust occurs very commonly and abundantly on the little prostrate creeping vine-like plant *Dichondra carolinensis* which occurs everywhere on the grassy hillsides and on grassy banks in the swamps. The rust causes a striking elongation and erection of the leaf petioles and a marked dwarfing of the leaves. The rust is apparently systemic, but comes to fruiting only on certain leaves, apparently those produced during periods of rapid growth. The tiny brown sori are sprinkled over the underside of the leaves. The rust appeared to be very scarce during the dry hot summer although the host was to be found everywhere. With the coming of autumn rains and consequent rapid growth, rusted leaves shot up in nearly every patch of *Dichondra* observed. The leaves formed during summer remained green and healthy. This rust is common throughout tropical and subtropical America, New Zealand and Australia. It was reported from Bermuda by Seaver (1916, p. 509).

Puccinia Dichromenae (Arth.) Jackson n. comb.

Uredo Dichromenae Arth. *Bull. Torrey Club*, XXXIII (1906), 31.

Dicaeoma* (?) *Dichromenae Arth. *N. Am. Fl.* VII (1920), 351.

III. Telia amphigenous, chiefly epiphyllous, deep seated, tardily naked, long covered by epidermis; teliospores irregularly ellipsoid or oblong 16–18 × 30–45 μ, apex rounded or obtuse, base rounded or narrowed to the pedicel, usually slightly constricted at septum; wall colourless or light cinnamon brown, smooth, 1–1$\frac{1}{2}$ μ thick, apex thickened 3–6 μ, pedicel short, colourless or slightly tinted.

On CYPERACEAE:

Dichromena colorata (L.) Hitch. Paget Marsh, Dec. 18, 1921, 49; Paget Marsh, Mar. 5, 1922, 71.

The rust is very abundant during December and January in Paget Marsh and Devonshire Marsh. Both leaves and culms are covered with the uredinia.

This species, heretofore reported only from the West Indies, Costa Rica and South America, has previously been known only in the uredinial stage. Telia were found in the collection made in February and are here described for the first time. The sori are badly parasitised so that exact description is difficult. *Dichromena colorata* appears to be a new host for this rust.

PUCCINIA HELIANTHI Schw. *Schr. Nat. Ges. Leipzig*, I (1822), 73.

Dicaeoma Helianthi-mollis Arth. *Résult. Sci. Congr. Bot. Vienne*, p. 334. 1906.

On CARDUACEAE:

Helianthus annuus L. (cactus flowered). Ogilvie, Paget West, Jan. 6, 1925, 89.

Sunflowers are frequently grown in Bermuda for ornament. This rust, usually common wherever sunflowers are grown, is conspicuous by its numerous blackish sori over the underside of the leaves. Nevertheless, although frequently sought for, this single collection is the only record of its occurrence in these islands known to the writers.

PUCCINIA HYDROCOTYLES (Link) Cooke. *Grevillea*, IX (1880), 14.

Caeoma Hydrocotyles Link, Willd. *Sp. Pl.* VI^2 (1825), 22.

Bullaria Hydrocotyles Arth. and Mains. *N. Am. Fl.* VII (1922), 489.

On AMMIACEAE:

Hydrocotyle verticillata Thunb. Pembroke Marsh, Sept. 6, 1921, and Paget Marsh, Dec. 18, 1921, 40.

This rust was first taken in March, 1919, in Pembroke Marsh on the whorled marsh pennywort. Its small brown uredinia are scattered over the lower surface of the peltate leaves. As the fungus causes little injury to the leaf it is difficult to detect from above. It is not common, at least during the summer months. It began to appear again in November, 1921, on a patch of this host which had all summer remained free of the rust. By January the rust was generally abundant. This rust is reported by Arthur from Bermuda (*N. Am. Fl.* VII, 489). It is common in Pembroke and Paget Marshes. This rust is widely distributed throughout the world.

Puccinia Lantanae Farl. *Proc. Am. Acad. Sci.* xviii (1883), 83.

Puccinia accedens Sydow. *Monog. Ured.* i (1902), 309.

Micropuccinia Lantanae Arth. and Jackson, Arthur. *Bull. Torrey Club,* xlviii (1921), 41.

On Verbenaceae:

Lantana involucrata L. (*Lantana odorata* L.). Common, June, 1921, 8; Jan. 12, 1926, 97; **N.Y.B.G. Herb.** Brown and Britton, Aug. 27–Sept. 21, 1921, 985; Brown, Britton and Seaver, Nov. 29–Dec. 14, 1912, **1236** and **1301**; Britton, Aug. 31–Sept. 20, 1905, **208**. There is also a specimen (part of type?) in this herbarium collected by Farlow, Jan. 1881, **1944***a* in the Farlow Herbarium, also another collected by Farlow, Jan. 1900.

This rust is exceedingly common throughout the year on the leaves of *Lantana involucrata*, the common sage bush, but has not been found on the other species of *Lantana* in Bermuda. This would seem to indicate the presence of specialised races in this species as the rust is reported on *Lantana Camara* from Cuba and Porto Rico. Careful search on the latter species in Bermuda has never disclosed the rust, although the two species of hosts often occur together, the former severely rusted.

The fungus causes yellow spots on the upper surface of the leaves, which below are slightly raised, due to a thickening of the leaf tissues, and are covered with the dark brown linear sori of the teleutospores. This is a microcyclic species, that is, producing telia only. While the rust is frequently met with during the summer months, it becomes much more general and destructive with the coming of the autumn rains. Although it does not appear to cause prompt defoliation it saps the vitality of the leaves, giving affected bushes a yellowish unhealthy hue. Seaver reports this rust from Bermuda (1916, p. 509). The type of this species was collected by W. G. Farlow in Bermuda in June, 1881, specimens of which were distributed in Ellis's *N. Am. Fungi*, No. 1052. (See also Hemsley, 1885, p. 103.) It is frequently attacked by another fungus, *Tuberculina* sp., which destroys the sori, giving them a dark purple colour. This rust is common throughout the western tropics.

Puccinia levis (Sacc. and Bizz.) Magn. *Ber. Deutsch. Bot. Ges.* ix (1882), 190.

Diorchidium leve Sacc. and Bizz.; Saccardo. *Michelia,* ii (1882), 648.

Puccinia Huberi P. Henn. *Hedwigia Beibl.* xxxix (1900), 76.

Dicaeoma leve Arth. and Fromme. *N. Am. Fl.* vii (1920), 286.

Dicaeoma Huberi Arth. and Fromme. *N. Am. Fl.* VII (1920), 287.

On POACEAE:

Paspalum sp. Luther, Somerset, Dec. 15, 1921, 48.

Mr. M. E. Luther discovered this rust on a rocky hillside in Somerset. The leaves and culms were literally covered with the uredosori of the rust. Telia were not found.

This is a common species on *Paspalum* and related hosts throughout Central America, the West Indies, and northern South America.

PUCCINIA MENTHAE Pers. *Syn. Fung.* p. 227. 1801.
Uredo Menthae Pers. *Syn. Fung.* p. 220. 1801.
Dicaeoma Menthae S. F. Gray. *Nat. Arr. Brit. Pl.* I (1821), 542.

On LAMIACEAE:

Mentha sp. Devonshire Marsh, June 1, 1922, 51.

The host of this cosmopolitan rust is very common about the margin of swamps. We have found the rust however but once on the northern margin of the Devonshire Swamp. This rust is worldwide on species of *Mentha*.

PUCCINIA POLYGONI-AMPHIBII Pers. *Syn. Fung.* p. 227. 1801.
Dicaeoma Polygoni-amphibii Arth. *Proc. Ind. Acad. Sci.* 1898, (1899), p. 184.

On POLYGONACEAE:

Persicaria punctata (Ell.) Small. Pembroke and Devonshire Marshes, Sept. 1921, 39; **N.Y.B.G. Herb.** Brown, Britton and Seaver, Nov. 29–Dec. 14, 1912, 1533.

This is a rather inconspicuous rust producing its uredinia on the underside of the leaves of the water smart-weed. This is a worldwide species having its aecia on species of *Geranium*. This rust has been reported previously from Bermuda by Seaver (1916, p. 509). It is found throughout the range of this host.

PUCCINIA PURPUREA Cooke. *Grevillea*, V (1876), 15.
Dicaeoma purpureum Kuntze. *Rev. Gen.* III^3 (1898), 470.

On POACEAE:

Holcus Sorghum L. Ogilvie, Agr. Station, Aug. 1927, 423; (?) **N.Y.B.G. Herb.** Brown, Britton and Seaver, Nov. 29–Dec. 14, 1912, 1535.

Holcus halapensis L. Paget, July, 1921, 18; St Georges, Nov. 16, 1921, 47.

This rust causes a marked reddening and striping of the leaves, severely injuring the host. Seaver (1916, p. 510) reports it as taken on sugar cane (*Saccharum officinarum*) in Bermuda. This was due to an error in determination of the host which was probably *Holcus Sorghum*. This is a common rust in the tropics.

Puccinia substriata Ell. and Barth. *Erythea*, v (1897), 47.
Dicaeoma substriatum Arth. *Résult. Sci. Congr. Bot. Vienne*, p. 344. 1906.

On Poaceae:

Chaetochloa geniculata (Lam.) Millsp. and Chase. Paget, Aug. 8, 1921, **20**; Roadside, Devonshire, Jan. 12, 1926; Walsingham, Mar. 6, 1924, **230**.

Chaetochloa verticillata (L.) Schrb. Paget, June 1921, 3; Aug. 8, 1921, **33**.

Specimens of this rust from Bermuda on *Chaetochloa verticillata* collected by S. Brown and N. L. Britton in 1905 are in the Arthur Herbarium, and its occurrence in Bermuda is recorded by Arthur and Johnston in *Mem. Torrey Bot. Club*, xvii (1918), 137.

This rust is quite common in Bermuda on the two species of Foxtail grass. The pustules are very large and abundant on the first-named host, covering leaves and sheaths with a dusty brown coating of uredospores. On the second host the pustules are few and scattered, not easily detected. This is the most common and most conspicuous rust of grasses in Bermuda. *Chaetochloa geniculata* is exceedingly abundant in untilled fields during the summer and is severely injured by the rust which kills the foliage, giving the fields a brown dead appearance in late summer. This rust is common throughout southern United States and the West Indies. It is a heteroecious species, the aecial host of which is unknown.

Puccinia superior (Arth.) Jackson n. comb.
Uredo superior Arth. *Bull. Torrey Club*, xxxi (1904), 5.
Dicaeoma superius Arth. *N. Am. Fl.* vii (1920), 351.

III. Telia hypophyllous and caulicolous, intercostal, linear, scattered or gregarious and occasionally confluent end to end, 0·2–1·0 cm. long, early naked, blackish brown, ruptured epidermis conspicuous; teliospores somewhat irregularly clavate or cylindrical 20–26 × 50–66μ, rounded or obtuse above, narrowed to pedicel below, slightly constricted at septum; wall chestnut brown, lighter below, smooth, 1·5–2μ, gradually thicker above, 6–9μ; pedicel firm, cinnamon brown, concolorous with base of spore, equalling the spore in length or shorter.

On Cyperaceae:

Fimbrystilis castanea (Michx.) Vahl. Warwick Marsh, Aug. 14, 1921 and Dec. 12, 1921, **32**.

This rust was collected in but one station about Warwick pond in the marshland. When first collected in August it was old and badly parasitised by *Darluca filum*. Another collection made in the same spot in December gave material in good

condition. The host is a new one for this rust. It is however known on other species of *Fimbrystilis* in the West Indies and South America.

The telia of this rust have not been heretofore described. All other collections known show only the uredinial stage. Since the December collection included abundant telia a description is given above. The rust is undoubtedly heteroecious in common with other species on this host family, but its aecial connection is unknown.

Puccinia triannulata (B. and C.) Jackson. *Mycologia*, xiv (1922), 111.

Uromyces triannulatus Berk. and Curt.; Berkeley, *Grevillea*, iii (1874), 56.

Puccinia merifica Diet. and Holw.; Dietel, *Erythea*, iii (1895), 79.

Bullaria triannulata Arth. and Mains. *N. Am. Fl.* vii (1922), 505.

On Carduaceae:

Borrichia arborescens (L.) DC. Shelley Bay, Oct. 16, 1921, 43, 44; Walsingham, Jan. 17, 1922, 54; Spanish Rock, Apr. 22, 1922, 68; **N.Y.B.G. Herb.** Britton, Hungry Bay, Sept. 1905, 205; **Farlow Herb.** Farlow, Dec. 1881.

This rust was collected by the senior author at Shelley Bay on both the glabrous and pubescent forms of the Sea-oxeye. The rust is easily detected by the more or less circular patches of sori, which surmount a slight swelling of the thick fleshy leaves. These telial patches vary in size from specks to half an inch in diameter over both sides of the leaves.

The rust was taken again in January at Walsingham. There was strong evidence here that in many shoots of the host the rust is systemic. Such shoots are slender and more actively vegetative than those about them. The sori on the leaves of such plants are very small and in long rows parallel with the mid-rib, usually one row on either side of the mid-rib on the underside of the leaf. The other plants about them are covered with the usual scattered more or less raised lesions crowned by a circle or tuft of sori. This rust also occurs in the Bahamas and along the coast of South Carolina, Florida and Texas. It has already been reported by Arthur from Bermuda (*N. Am. Fl.* vii, 506).

Puccinia tubulosa (Pat. and Gaill.) Arth. *Am. Jour. Bot.* v (1918), 464.

Aecidium tubulosum Pat. and Gaill. *Bull. Soc. Myc. Fr.* iv (1888), 97.

Dicaeoma tubulosum Arth. and Fromme. *N. Am. Fl.* VII (1920), 288.

On POACEAE:

Oplismenus hirtellus (L.) R. and S. Hillside, Paget East, Aug. 24, 1921, **34**; Paget Marsh, Feb. 12, 1922, **57**; Hillside, Paget East, Jan. 1926, **90**.

The uredo stage only has been found in Bermuda, although careful search was several times made for the telia. The rust is quite common on the underside of the leaves of this little prostrate grass. It causes the leaves to become yellow and die. This rust, although common on a number of grass hosts throughout the American tropics, was found in Bermuda only on this host which appears to be a new one for it. Its aecidial stage, which is very common in Porto Rico on *Solanum torvum*, was not found in Bermuda although this host occasionally occurs in gardens there. This rust is common on species of *Paspalum* and other grasses throughout the western tropics and Asia.

RAVENELIA INDIGOFERAE Tranz. *Hedwigia*, XXXIII (1894), 369.

On FABACEAE:

Indigofera suffruticosa Mill. Walsingham, Jan. 17, 1922, **55**; **Farlow Herb.** Farlow, Jan. 1881.

This fungus was very abundant on the leaves and seed pods of the wild indigo at Walsingham in January, 1921. It forms grey brown pustules on the underside of the leaflets. The lesions are sometimes rather large and marked by a yellowish depression on the upper side. The fungus appears to cause defoliation. This rust is widely distributed throughout the western tropics. It is reported from Bermuda by Arthur (*N. Am. Fl.* VII, 144).

TRANZSCHELIA PUNCTATA (Pers.) Arth. *Résult. Sci. Congr. Bot. Vienne*, p. 340. 1906.

Aecidium punctatum Pers. *Ann. Bot. Usteri*, XX (1796), 135.

Puccinia Pruni-spinosa Pers. *Syn. Fung.* p. 226. 1801.

On AMYGDALACEAE:

Amygdalus persica L. Hamilton, June 1921, **4**; **N.Y.B.G. Herb.** Brown and Britton, Aug. 27–Sept. 21, 1912, **917**; Brown, Britton and Seaver, Nov. 29–Dec. 14, 1912, **1536**.

This is the common rust of peaches. It is very abundant in Bermuda where it causes a severe defoliation of the trees during the summer months (Whetzel, 1923, p. 29). It is easily detected by its abundant uredo pustules which cover the underside of the leaves. Affected foliage turns yellow and falls. The trees are thus forced to put out new leaves constantly which is a heavy drain on the fruiting of the trees. This disease we believe largely

accounts for the straggly growth and light set of fruit generally to be observed in Bermuda peach trees. Dusting with sulphur should effectively protect the foliage.

This fungus occurs on peaches throughout the warm regions of both hemispheres in its uredinial form only. In temperate regions it produces both telia and aecia in addition to uredinia. It is a heteroecious species having its aecia on species of *Anemone*, *Hepatica* and *Thalictrum*. Bishop (1902, p. 10) first reported this rust from Bermuda. It was again reported by Seaver (1916, p. 510).

Uredinopsis Copelandi Sydow. *Ann. Myc.* II (1904), 30.
Uredinopsis Atkinsonii Magn. *Hedwigia*, XLIII (1904), 123.
Milesia Copelandi Arth. *Résult. Sci. Congr. Bot. Vienne*, p. 337. 1906.
Milesia Atkinsonii Arth. *Résult. Sci. Congr. Bot. Vienne*, p. 337. 1906.

On Polypodiaceae:

Dryopteris Thelypteris (L.) A. Gray. Pembroke Marsh, Feb. 5, 1926, 86; Ogilvie, Pembroke Marsh, June 29, 1927, 381.

This rust causes a browning of the pinnae of the fronds. The yellow uredo sori cover the underside of the diseased areas. Badly rusted fronds soon blacken and shrivel. These two collections from the same station are the only ones known from Bermuda. The aecial stage occurs on species of *Abies* in northern United States and Canada. The other spore forms are quite common in northern United States and Canada.

Uredinopsis macrosperma (Cooke) P. Magn. *Hedwigia*, XLIII (1904), 122.
Uredo macrospermum Cooke. *Grevillea*, VIII (1879), 71.
Uredinopsis Pteridis Diet. and Holw. *Ber. Deuts. Bot. Ges.* XIII (1895), 331.
Aecidium pseudo-basalmeum Diet. and Holw. *Erythea*, VII (1899), 98.
Milesina Pteridis Syd. *Monog. Ured.* III (1915), 481.

On Polypodiaceae:

Pteridium caudatum (L.) Maxon (*Pteris caudata* L.). Paget Marsh, Aug. 14, 1921, 31; March 14, 1922, 65.

This rust was collected in Paget Swamp where it was common in August, 1921, on the bracken fern. It causes dead areas between veinlets on the pinnae. The uredospores ooze from the sori in tiny white masses on the under side of the leaves. This species is worldwide in its distribution. The aecial stage occurs on species of *Abies* in United States. This rust has been reported from Bermuda by Arthur (*N. Am. Fl.* VII, 684).

Uredinopsis Osmundae Magn. *Hedwigia*, xliii (1904), 123. *Milesia Osmundae* Arth. *Résult. Sci. Congr. Bot. Vienne*, p. 337. 1906.

On Osmundaceae:

Osmunda cinnamomea L. Paget Swamp, Apr. 22, 1922, **64**.

This rust was quite abundant on the common cinnamon fern in Paget Swamp causing yellowish brown flecks on the pinnae. It is common on species of *Osmunda* throughout eastern United States.

Uredinopsis struthiopteridis Stormer. *Bot. Notiser*, 1895 (1895), 81.

On Polypodiaceae:

Anchistea virginica (L.) Presl. Devonshire Marsh, Aug. 10, 1921, **25**.

Like most species of *Uredinopsis* this rust causes dead areas in the frond, extending from the mid-vein of the pinna to the margin between the side-veins. The diseased area is first yellow, then brown and dead. The uredospores are produced from sunken sori, oozing out as tiny white masses on the underside of the diseased area. This rust is very common in Bermuda. It is not a common species on this host in continental America, occurring in New England and northward. It is also known from Europe.

Uredo nominata Arth. *Bull. Torrey Club*, xlix (1922), 194.

On Iridaceae:

Sisyrinchium bermudianum L. Common during winter and spring, **2, 94**.

This rust maintains itself concurrently with the entire foliage period of its host. The host shows practically no green above ground from July 1st to November. Early in November green leaves begin to push up from the thickened resting root clusters. About Dec. 1, 1921, well-developed purple lesions with mature uredo pustules in them were found. Evidently the rust had appeared at least ten days or two weeks earlier. It was again collected in abundance during January, 1926. It was collected frequently during June, 1921, on the dead and dying leaves and flower stalks. The type specimen of this rust collected in 1908 at St David's by S. Brown (**N.Y.B.G. Herb. 611**) is deposited in the Arthur Herbarium. This rust is not known outside Bermuda. Although frequent search was made for other spore stages during the year 1921–2 no telia or aecia were discovered. Just how it survives the period of dormancy of its host is puzzling. This is the only endemic rust in Bermuda.

Uredo Parthenii Speg. *Anal. Mus. Nac. Buenos Aires*, VI (1899), 239.

On Carduaceae:

Parthenium hysterophorus L. Common, Aug. 28, 1921, 35.

This rust is frequently abundant on leaves and stems of the very common weed, *Santa Maria*. It produces its rather large dark sori in great abundance over the undersides of the affected leaves. The leaves are somewhat dwarfed and die prematurely. It was found only during the summer months in any abundance. It was taken once on some old plants during the winter but although the host continues to grow and blossom the rust does not seem to thrive during the winter season. This appears to be the first report of this rust from North America. It has been known heretofore only from South America.

Uredo Sapotae Arth. and Johnston. *Mem. Torrey Club*, XVII (1918), 169.

On Sapotaceae:

Sapota achras Mill. Fruitlands, Warwick, June 16, 1921, 1; Jan. 14, 1926, 95.

This very inconspicuous rust has been found in Bermuda only at Fruitlands in Warwick. It was first collected in June, 1921, when it was evidently just beginning to develop. It was more abundant on the same trees in August. It appears to reach its maximum development during the winter months, from January to March, as was observed in both 1922 and 1926. It was found severely attacking the broad cotyledons of seedlings under these trees in January, 1926. Affected leaves usually show little injury, but where abundant the rust causes a slight yellowing of the foliage. The uredo pustules are very small, much scattered and not easily detected. Known heretofore only from Cuba and Nassau in the Bahamas.

Uredo Vincetoxici DC.

This species was reported by Berkeley (1875, p. 351) as occurring in Bermuda on leaves of Oleander. Through the kindness of the Director of the Royal Botanical Gardens at Kew I have had the opportunity to examine what is undoubtedly the specimen on which Berkeley's record is based. The specimen consists of three leaves glued to the herbarium sheet and bearing the label "*Uredo Vincetoxici* DC. Challenger Expedition, Bermuda, on Oleander." Examination proves these to be leaves of *Solidago sempervirens* L. and not Oleander. There is present on the leaves abundant sori of *Coleosporium Solidaginis* (Schw.) Thüm.

Uromyces appendiculatus (Pers.) Fries. *Summa. Veg. Scand.* (1849), 514. Not *Uromyces appendiculatus* Ung., 1836.

Uredo appendiculata Pers. *Ann. Bot. Usteri*, xv (1795), 16.

Nigredo appendiculata Arth. *Résult. Sci. Congr. Bot. Vienne*, p. 343. 1906.

On Fabaceae:

Dolichos Lablab L. Whetzel and Ogilvie, near Harrington House, Jan. 21, 1926, **87**.

This is the common bean rust known throughout the world on cultivated beans and on many other species of *Phaseolus*. That it has not attacked the cultivated garden beans in Bermuda is probably because of the absence in the Islands of the biologic strain of the fungus peculiar to cultivated beans.

Uromyces bidenticola (P. Henn.) Arth. *Mycologia*, ix (1917), 71.

Uredo bidenticola P. Henn. *Hedwigia*, xxxvii (1898), 279.

Klebahnia Bidentis Arth. *Mycologia*, vii (1915), 196.

On Carduaceae:

Bidens pilosa L. (*Bidens leucantha* L.). Common, June 1921, **12**.

The white beggar ticks, a very common weed of field, garden and roadside, is generally affected by this rust which forms dark brown clusters of sori of various sizes over the under surface of the leaves. The plants are often severely injured by the rust. This is an autoecious species having pycnia, uredinia and telia all on the same host. It does not have aecia in its life cycle. It is common throughout the western tropics and the Canary Islands. A microcyclic species, *Uromyces Bidentis*, occurs on this same host often along with *Uromyces bidenticola* in Porto Rico (see *Mycologia*, ix, 71), but has not been found in Bermuda.

This rust is much more common and severe during the summer. In fact it was hard to find during the winter months although the host could always be found and often in blossom. It has previously been reported from Bermuda by Arthur (*N. Am. Fl.* vii, 481).

Uromyces caryophyllinus (Schrank) Wint. *Rab. Krypt. Fl.* I^1 (1881), 149.

Lycoperdon caryophyllinum Schrank. *Baier. Fl.* ii (1789), 668.

Nigredo caryophyllina Arth. *N. Am. Fl.* vii (1912), 246.

On Caryophyllaceae:

Dianthus caryophyllus L. Pomander Gate, Paget, Apr. 16, 1922, **62**; May 9, 1922, **70**.

This rust developed very abundantly on certain varieties of *Dianthus caryophyllus* planted in the garden at Pomander Gate in Paget, where during the early spring it ruined many plants. It was first reported from Bermuda by Whetzel (1923, p. 29). Collections in best condition were made in April. Ogilvie (1925, p. 41) again reports it on carnations in 1924. This rust is widespread on carnations in greenhouses throughout temperate North America; it also occurs in Europe and Japan.

Uromyces Fabae (Pers.) de Bary. *Ann. Sci. Nat.* IV, xx (1863), 80.
Uredo Fabae Pers. *Neues Mag. Bot.* I (1794), 93.
Uromyces appendiculatus Ung. *Einfl. Bodens*, p. 216. 1836.
Uromyces Viciae Fuckel. *Symb. Myc.* p. 62. 1869.
Nigredo Fabae Arthur. *N. Am. Fl.* VII (1912), 251.

On Fabaceae:

Vicia Faba L. Ogilvie, Agr. Sta., Mar. and Apr. 1926, **100***a*, **100***b*.

This rust of the broad bean or Portuguese bean as it is called in Bermuda is worldwide in its occurrence on this host. It also affects many species of *Lathyrus* and other species of *Vicia*. Although frequently sought by the senior author in Bermuda it was not known in the Island until taken by Mr Ogilvie (1927, p. 40). He first found it in Devonshire in May 1924. His first report of it (1925, p. 37) was in error in referring it to *Uromyces appendiculatus*.

The powdery brown uredo sori thickly cover the underside of the leaves. The telia develop abundantly on the stems.

Uromyces Howei Peck. *Ann. Rept. N.Y. State Mus.* XXX (1879), 75.
Trichobasis Howei Peck. *Ann. Rept. N.Y. State Mus.* XXIII (1873), 58.
Uromyces Asclepiades Cooke. *Grevillea*, V (1877), 152.
Nigredo (?) Howei Arth. *N. Am. Fl.* VII (1912), 264.

On Asclepiadaceae:

Asclepias curassavica L. Along south shore road, Smith's Parish, Jan. 17, 1922, **52**; Walsingham, Jan. 21, 1926, **93**; Paget Marsh, Jan. 31, 1926, **92**.

Although the host is very common, the rust has been taken in but three stations. All the plants were literally coated with it. The lower affected leaves were yellow and falling while the green leaves above were dotted over the underside with the cushion-like dark brown sori. The Paget Marsh collection shows large lesions on the stem. The fungus here was parasitised by a species of *Tuberculina*. This rust is common on species of *Asclepias* throughout the world.

Uromyces leptodermus Sydow; Syd. and Butler, *Ann. Myc.* IV (1906), 430.
Nigredo leptoderma Arth. *N. Am. Fl.* VII (1912), 224.
On Poaceae:
Panicum barbinode Trin. Pembroke Marsh, Aug. 8, 1921, **21**.

The uredinial stage of this rust is very common on para grass along the edge of marshes. The uredinia are scattered and inconspicuous on the lower side of the leaves. It causes the leaves to become yellow and dry up. It has not been observed to injure seriously this valuable fodder grass in Bermuda. It does not appear to have been reported previously from Bermuda. It is common in the West Indies and India.

Uromyces Limonii (DC.) Lev.; Cooke, *Micr. Fungi*, p. 211. 1865.
Puccinia Limonii DC. *Fl. Fr.* II (1805), 595.
Uromyces Statices Berk. and Curt. *Proc. Am. Acad.* IV (1858), 126.
Nigredo Limonii Arth. *Résult. Sci. Congr. Bot. Vienne*, p. 344. 1906.
On Plumbaginaceae:
Limonium carolinianum (Walt.) Britton (*Statice Caroliniana* Walt.). O. Degener, Hungry Bay, Sept. 5, 1921, **37**; Natural Arches, near Tuckerstown, Nov. 6, 1921, **41**; Walsingham, Feb. 2, 1922, **56**; **Farlow Herb.** Farlow, 1881.

This is a striking rust, producing an abundance of its large dark masses of sori, over the undersides of the erect leaves and the stems of the sea lavender along sea-shore marshes. It was found in abundance at Walsingham about the larger pool near Tom Moore's Calabash tree. This rust is widely distributed throughout the world. This appears to be the first report of its occurrence in Bermuda.

Uromyces Medicaginis Pass. See under *Uromyces striatus* Schroet.

Uromyces perigynius Halsted. *Jour. Myc.* V (1889), 11.
Nigredo perigynia Arth. *Résult. Sci. Congr. Bot. Vienne*, p. 344. 1906.
On Cyperaceae:
Carex albolutescens Schw. Devonshire Swamp, Aug. 10, 1921, **23**.

This rust was collected in August, 1921, on the leaves and stalks of the sedge in the Devonshire Swamp. It does not appear to have been taken before on this host. The aecial stage of this

rust occurs on species of the Carduaceae. This rust is known in widely separated localities in North America.

Uromyces proeminens (DC) Pass.; Rabenhorst, *Fungi Eur.* 1795. 1874.
Uredo proeminens DC. *Fl. Fr.* II (1805), 235.
Nigredo proeminens Arth. *N. Am. Fl.* VII (1912), 259.
On Euphorbiaceae:

Chamaecyce nutans (Lag.) J. K. Small. (*Chamaecyce Presleii* (Guss.) Arth.) Shelley Bay, July, 1921, 15.

Chamaecyce hyssopifolia (L.) J. K. Small (?); **N.Y.B.G. Herb.** Brown, Britton and Seaver, Nov. 29–Dec. 14, 1912, 1330 and 1331.

Chamaecyce prostrata (Ait.) J. K. Small. St David's Island, July 8, 1921, 16; **N.Y.B.G. Herb.** Brown and Britton, Aug. 27–Sept. 21, 1912, 851, 1357.

Poinsettia cyathophora (Murr.) S. Brown. St David's Island, July 7, 1921, 14; **N.Y.B.G. Herb.** Brown, Britton and Seaver, 1208*b*, 1250.

This is a most interesting rust. It occurs on several species of *Chamaecyce* and *Poinsettia*. Seaver (1916, p. 509) reports it from Bermuda on *Poinsettia heterophylla* (in error, as all his specimens are on *Poinsettia cyathophora*), *Chamaecyce Blodgettii* (an error for *Chamaecyce prostrata*), *Chamaecyce hyssopifolia* and *Chamaecyce prostrata*.

Poinsettia cyathophora is a common annual weed of waste or uncultivated fields. It was once regarded as a form of *Poinsettia heterophylla*. The senior author has proved it to be distinct by a comparison of plants grown from seed. It is frequently severely attacked by this rust, the underside of its leaves being covered with the prominent dark sori of the telial stage. While *Poinsettia heterophylla* has never been found affected with the rust in Bermuda it is however a host of this rust in the West Indies. *Chamaecyce nutans*, the upright spotted spurge, is a large erect weed often one to two feet high. The aecial stage of the parasite is systemic usually in one or more branches of this host. These branches are usually easily detected by the slightly dwarfed, blanched and erect leaves. The undersides of such leaves are covered completely with the pale yellow cluster cups or aecia. The other leaves and the leaves of adjacent plants bear scattered over their under surface the dark brown sori of the uredinial and telial stages. Only a relatively small number of the plants in a population exhibit the aecial stage. *Chamaecyce prostrata*, the prostrate spurge, is the smallest of the spurges, with the radially disposed branches lying flat on the ground, and small and purplish leaflets. It is a striking prostrate little weed of paths and

waste lands. The aecial stage has a marked effect on the structure and habit of the affected branches of this host. They grow erect, slender and with decidedly fewer paler leaflets on whose undersides the cluster cups form a continuous layer. The writers feel sure from field observations that we have here two or more specialised races of this rust. The peculiar distribution of affected plants of one species commonly occurring along with unaffected plants of the other host species, seems in itself strong circumstantial evidence for this view.

Uromyces Rhynchosporae Ell. *Jour. Myc.* VII (1893), 274.
Nigredo Rhynchosporae Arth. *Résult. Sci. Congr. Bot. Vienne*, p. 344. 1906.

On Cyperaceae:

Rhynchospora distans (Michx.) Vahl. Devonshire Marsh, Aug. 10, 1921, **24**.

A specimen on the same host from the same locality in Bermuda is in the Arthur Herbarium, having been secured from a phanerogamic specimen in the New York Botanical Garden, collected by S. Brown and N. L. Britton in 1905. It is recorded from Bermuda by Arthur in the *N. American Flora*.

This rust is to be found throughout the West Indies on this and other species of *Rynchospora*. In its uredinial stage it is sometimes confused with *Puccinia angustatoides* (*Mycologia*, IX, 68). Specimens taken during February in the same locality were all badly parasitised by *Darluca filum*.

Uromyces Scirpi (Cast.) Burrill. *Bot. Gaz.* IX (1884), 188.
Uredo Scirpi Cast. *Cot. Pl. Mass.* p. 214. 1845.
Nigredo Scirpi Arth. *Résult. Sci. Congr. Bot. Vienne*, p. 344. 1906.

On Cyperaceae:

Scirpus americanus Pers. Paget Marsh, Aug. 14, 1921, **28**.
Scirpus Olneyi A. Gray. Warwick Marsh, Aug. 14, 1921, **29**; Shelley Bay, Oct. 16, 1921, **45**.

This species was collected in 1914 by Brown, Britton and Bissett, **N.Y.B.G. Herb. 1916**, and forms the basis of the report of *Puccinia Scirpi* DC. from Bermuda in the *North American Flora*. An examination of this specimen, however, shows that the urediniospores have equatorial germ pores, a character diagnostic of *Uromyces Scirpi*. This is a very common rust on Olney's bulrush along the margin of marshes. It produces its yellow uredinia in abundance on the three-sided stalks of this rush. It frequently kills back the stalks. The second host, *Scirpus Olneyi*, appears to be new for this rust. This rust is common throughout the United States on species of *Scirpus*. Its aecial

stage occurs on species of *Cicuta*, *Sium* and *Glaux*. It is also known in Europe.

Uromyces striatus Schroet. *Abh. Schles. Ges.* xlviii (1870*), 11.

Uromyces Medicaginis Pass.; Thümen, *Herb. Myc. Oecon.* 156, 1874.

On Fabaceae:

Medicago lupulina L. Common, June, 1921, **6**.

Medicago hispida Willd. (*Medicago denticulata* Willd.). Common, July, 1921, **17**; Agr. Station Grounds, Feb. 20, 1922, **66**; **N.Y.B.G. Herb.** Brown, Britton and Seaver, Nov. 29–Dec. 14, 1912, **1358**; Massee (1898, p. 133) records a collection of the rust on this host by Capt. H. A. Cummins near St Georges (date?). The specimen is in the Herbarium at Kew.

This rust is very common on the two species of *Medicago* forming its dark brown uredinia over the under surface of the leaves. Seaver records this rust from Bermuda on *Medicago denticulata* (*Medicago hispida*), under the name of *Nigredo Medicaginis* (Pass.) Arth. Arthur and Johnston also record it from Bermuda (*Mem. Torrey Bot. Club*, xvii, 128). The rust is very common and abundant on *Medicago hispida* during March and later, as at that time the host is at its maximum development. During the summer it is much suppressed.

This rust occurs on species of *Medicago* throughout the world.

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* Regarding the name here used for this fungus, Dr. J. C. Arthur writes in a letter of Jan. 21, 1927, "*Uromyces striatus* Schroet., Abh. Schles. Ges. xlviii, 11, was published in 1870 (not 1869) and seven hosts were named, *Genista tinctoria*, five species of Medicago and *Trifolium arvense*. With the strict interpretation used by me in 1912, associating the name with the rust on the first host mentioned, *U. striatus* belonged to what is now called *U. Genistae-tinctoriae*, a rust that does not occur in America, and hence its synonomy does not appear in the North American Flora.

"I now think that Schroeter's name should apply to the *Medicago* rust, and as it has about four years' precedence, *U. Medicaginis* Pass. must drop into synonomy. I regret that this matter was not called to my attention soon enough to be entered in the supplement to the flora."

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THE PARASITISM OF THE HOP LEAF-SPOT FUNGUS CERCOSPORA CANTUARIENSIS.

(With Plate I and 1 Text-figure.)

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INTRODUCTION.

IN September, 1922, Professor E. S. Salmon found in a hop garden of Canterbury Goldings at Canterbury, a number of hop leaves showing diseased spots suggesting fungal infection, and microscopic examination revealed the presence on the spots of a species of *Cercospora* with very large conidia. As the fungus did not conform to descriptions of known representatives of the genus it was described (2) as a new species *Cercospora cantuariensis* Salmon and Wormald, and a brief description of the disease with an illustration of a naturally infected leaf was also published (3). At the time the fresh material was examined it was not realised that the disease or the fungus might be of any special interest and although herbarium specimens were preserved the fungus was not isolated in culture. Some weeks later when it was found that the fungus had not previously been

described the desirability of having it in culture for further study was manifest. As no fresh material was then available conidia were removed from the dry herbarium specimens and placed on culture media, but none of them germinated. Particles of the spots were then teased out and placed on prune agar plates. Within a few days hyphae grew out from the edges of the leaf particles and later gave rise to cultures which appeared to be the same fungus in all cases, but, as no spores resembling those found on the leaf-spots were produced in these cultures, the fungus could not at the time be identified as the one found on the living leaves. The constant association of the fungus with the spots, together with the fact that many species of *Cercospora* are known to be parasitic, suggested that the fungus under consideration was also parasitic, and that, assuming the fungus in culture was the original one of the spots and not a contamination, it would probably sporulate if inoculated into living hop leaves. For various reasons it was not possible to carry out such inoculations until 1924 when it was found that hop leaves could be readily infected with the fungus in culture, and the resulting infection spots gave rise to *Cercospora* fructifications similar to those found nearly two years previously on the naturally infected leaves. Single spore cultures were then obtained and used in the inoculations. The inoculations on hop leaves were repeated with one of these single spore strains with positive results, and the pathogenicity of the fungus was established.

In the previous descriptions of the disease it was assumed that the fungus found on the spots was the cause of the disease, although no experimental evidence had at that time been obtained. The object of the present paper is to prove the parasitism of *C. cantuariensis*.

The Disease and the Associated Fungus.

The disease has been recorded only once, though Blattný (1) mentions a species of *Cercospora* (which apparently is not *C. cantuariensis*) on hop cones in Czecho-Slovakia. In the outbreak at Canterbury the fungus was found on the leaves only, some of the more heavily infected leaves showing as many as twenty infection spots. The spots were roughly circular with a greyish (almost white) central portion 1–5 mm. in diameter, bordered by a dark purplish-brown line surrounded by a yellowish zone which gradually merged into the green of the normal parts of the leaf. When spots were in close proximity the yellow zones coalesced to form comparatively large areas of discoloured leaf surface. The bright colouring of the spots was more defined on the upper surface of the leaves than on the lower side.

The conidia of the fungus projected from the lower surface of the grey central portion of the spots and with a lens could easily be seen as hair-like processes. Conidia taken from a naturally infected leaf showed wide variation in the number of septa and in the dimensions. The septa were mostly 5 or more up to 14, but occasionally there were fewer septa, and one conidium 136μ long was continuous, while another 80μ long had 3 septa. The dimensions of conidia with 5–14 septa were 114–380 × 12–19μ. Comparatively few conidia from the original leaves were measured, and later, when conidia were

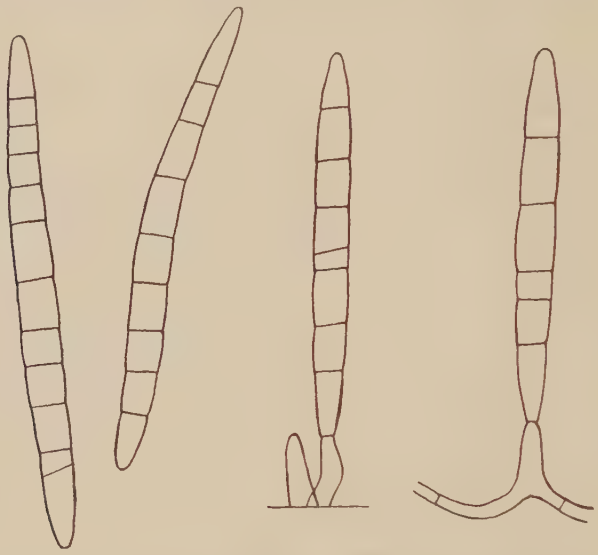

Fig. 1. Conidia and conidiophores of *Cercospora cantuariensis*.

produced on the artificially infected leaves, further measurements were taken. These conidia were, on the whole, even larger than those from natural infections, which may have been due to the conditions under which they were produced, as the inoculations were made on plants growing in a moist atmosphere in a cool greenhouse. Of sixty-eight conidia taken at random the septa were 5–19 in number and the dimensions of the spores 135–508 × 10–21μ with an average of 250 × 13·5μ. They sometimes reached a length of half a millimetre and so could be seen with the naked eye when the lower surface of a spot was held up to a window so that the conidia were viewed in profile. As these conidia were produced under artificial conditions their dimensions should not, perhaps, be taken as typical, but as on spots of the naturally infected leaves growing in the open many conidia

were found from 200 to 300μ in length, the large size of the conidia is seen to be a striking character of this fungus. The conidia are pale brown, cylindrical with tapering ends, straight or slightly curved and often slightly constricted at the septa. Each is borne on a relatively short conidiophore 25–35μ in length.

Cultural Studies of the Fungus.

The original cultures were obtained, in 1922, from dried particles of infected spots, and the fungus was kept (by sub-culturing on prune agar) until June 1924 when inoculations were made on hop leaves, and by the use of conidia obtained from the resulting infection spots, isolations were made on prune agar plates. By reason of their large size no difficulty was experienced in isolating the conidia and obtaining mono-spore cultures. On the prune agar plates kept at room temperature (18°–20° C.) the conidia readily germinated and within twenty-four hours the germ tubes grew out to a distance of about 1·5 mm. Usually germ tubes grew out from both terminal cells and also from one or two other cells of a conidium; in one conidium two non-terminal cells gave rise to germ tubes. Sporelings transferred to fresh plates grew away freely and when nine days old each formed a circular mycelial disc 2·5 to 3 mm. in diameter, consisting (macroscopically) of dark brown dendritic lines centrally, with a more hyaline peripheral zone. In the older, darker parts of the cultures the hyphae bore numerous, intercalary, dense, dark spherical cells, resembling chlamydospores. It was later found that on certain media the entire culture was composed almost entirely of these chlamydospore-like cells. Similar bodies have been found by Westerdijk and Van Luijk (4) in cultures of *C. Carvi*.

To induce the fungus to develop conidia in pure culture for inoculation experiments, various culture media were tried, but on none of them were the typical *Cercospora* fructifications produced.

The mode of growth of the fungus on the different media was not without interest however, particularly with reference to the production of the chlamydospores; on malt agar they were absent altogether; on glycerinated potato the mycelium was a dense mass of these cells and on the other media tried they were produced in different degrees. Notes taken on tube cultures (slopes) four weeks old were as follows:

Prune agar (prunes 1 per cent.). Growth good, aerial mycelium scanty, chlamydospores produced; so far as these can be seen at upper end of slope they are well separated and singly or in pairs; mycelium and chlamydospores brown, causing the culture to be

dark brown; cells of hyphae mostly elongate with a row of large guttules, hyphae very variable in width, some almost setaceous.

Prune agar (Difco). Practically indistinguishable from above, chlamydospores appear to be not quite so numerous.

Carrot agar. Growth good, very like that on prune agar, but chlamydospores more numerous.

Malt agar. Colourless, aerial mycelium scanty, no chlamydospores, but mycelial knots present in places, numerous setaceous hyphae.

Potato dextrose agar. Dirty white, cottony aerial hyphae, submerged mycelium very dark, chlamydospores very numerous, in clumps or series.

Potato agar. Aerial mycelium almost white, hyphae in the medium growing in a zigzag manner, chlamydospores very numerous, cells of hyphae short, barrel-shaped or rounded.

Potato mush agar. Aerial mycelium rather scanty, submerged mycelium very dark, zigzag growth more pronounced, cells of hyphae in older parts short, barrel-shaped or rounded and very dark, some darker than the rest, these probably corresponding to the chlamydospores of the other cultures.

Potato. Good growth, 2·5 cm. long, very dark brown, consisting of chlamydospore-like cells.

Glycerinated potato. Growth restricted, roughly circular and only 6 mm. in diameter, pulvinate, conglomerate, very dark brown and consisting of very dark rounded cells.

Inoculation Experiments.

As conidia had not yet been found in pure cultures primary inoculations were made with mycelium taken from plate cultures.

A preliminary experiment (No. 1) was carried out in 1924. In 1925 and 1926 similar primary inoculations were made but these were followed by inoculations made by placing on the leaves drops of a suspension (in sterilised water) of conidia taken from a primary infection spot. The results of these conidial inoculations were similar to those obtained by inoculating with mycelium from pure plate cultures so that it may be concluded that the conidia are themselves capable of directly infecting the leaves. All the inoculations were made on plants growing in pots in a cool greenhouse.

Experiment 1. A young hop plant (variety Canterbury Golding), growing in a pot in the greenhouse, was inoculated on June 3rd, 1924, by placing on the leaves particles taken from a prune agar plate culture, and puncturing the leaves at those spots. Two leaves were each inoculated at five spots. A control for each inoculated leaf was the corresponding leaf at the same

node, this leaf being punctured but not inoculated. The plant was then covered with a bell-jar to maintain a moist atmosphere.

By June 17th each inoculated spot had given rise to a dead area about 5 mm. in diameter bearing numerous conidia of *C. cantuariensis* on the under side. Apart from the actual puncturing there was no injury on the control spots.

By this experiment it was first proved that the fungus obtained in culture from the dried particles of diseased spots was really *C. cantuariensis*.

From one of the infection spots of this experiment conidia were isolated on a culture plate and the subsequent experiments with mycelium were carried out with monospore strains.

Experiment 2. A young hop plant (variety Canterbury Golding) was inoculated (April 15th, 1925) by puncturing each of four leaves at three points and placing mycelium from a pure culture on the punctures.

Positive results were obtained on all the spots of three leaves; those on the fourth leaf failed. The infected spots on May 2nd were 9–14 mm. in diameter and bore conidia of *C. cantuariensis*.

Experiment 3. A plant was inoculated by placing conidia, suspended in drops of water, on two pairs of leaves, at three points on each leaf. One leaf of each pair was inoculated on the upper side, the other on the lower side. The inoculations were carried out on May 2nd, using conidia from one of the infection spots of Experiment 2. On May 6th all the inoculated spots appeared as pale yellowish areas, and on May 20th the spots bore the typical conidia. Leaves not inoculated remained healthy.

This experiment showed that the fungus was able to penetrate leaves from either the upper or the lower side. Later inoculations with conidia were therefore made on the upper surface for convenience.

Experiment 4. Plants of various well-known varieties were inoculated with conidia to ascertain whether any were immune from the disease. Each plant was inoculated on four leaves, at three points on each leaf without puncturing. Two plants of the Tutsham variety were inoculated in this way and one each of the varieties Canterbury Whitebine, Colgate's, Bramling, Fuggle's, Rodmersham Golding, and Tolhurst.

On the Canterbury Whitebine and one of the Tutsham plants some of the inoculated points showed as pale spots on the third day after inoculation. Two days later these spots were 2 mm. in diameter, each with a whitish centre and dark marginal line.

Infection on the other plants did not show until later but all showed some infection spots within fifteen days. Of the twelve inoculations on each plant the number of positive results was as follows:

Canterbury Whitebine	3	Fuggle's	3
Bramling	8	Tolhurst	7
Rodmersham Golding	10	Tutsham	6 on one plant
Colgate's	8		11 on the other

As the plants were grown under the same conditions it would appear that each of the varieties tried is as susceptible to this disease as is the Canterbury Whitebine.

Experiment 5. A plant of the Tutsham variety was inoculated (March 31st, 1926), with mycelium from a plate culture, on the leaves of two bines.

(1) On one bine three pairs of leaves were inoculated, each leaf at three places, one on each lobe; the lateral lobes were punctured at the inoculated spots but not the terminal lobe. One leaf of each pair was inoculated on the upper side, the other on the lower side.

(2) On the other bine four leaves were inoculated on the upper side by punctures at each spot, three inoculation spots on each leaf.

On April 8th all the punctured spots showed infection. There was no evidence of infection at the unpunctured spots except in one where the tip of the leaf was infected by inoculation from below and in another where two small infection spots occurred where inoculation had been made on the upper surface. The inoculated punctured spots were from 0·5 to 1·3 cm. in diameter. From bine (2) one infected leaf had fallen.

On April 19th all the spots showed evidence of infection, which appeared to have been delayed in those inoculations carried out without wounding. From bine (2) two other infected leaves had fallen.

Experiment 6. On April 14th inoculations, with conidia in drops of water applied with a platinum loop, were made on two plants (*a*) and (*b*). Each leaf was inoculated at three places (one on each lobe). Only one leaf of the pair at any one node was inoculated with conidia; the other was used as a control by applying drops of sterile water only. Six leaves on plant (*a*) and five on (*b*) were thus inoculated, with a corresponding number of controls.

By April 19th twenty-two of the inoculations had produced infection spots; these were 1–3 mm. in diameter and showed the usual grey centre bordered by a dark line; the tissues bordering on the infected spots were turning yellow. Later six more of the inoculations showed evidence of infection so that by April 30th twenty-eight of the thirty-three inoculations had produced infection spots which were by that time up to 1·5 cm. in diameter and bore conidia on the lower surface. The control leaves showed no infections.

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CERCOSPORA CANTUARIENSIS SALM. AND WORM.

Experiment 7. Leaves on two plants (*c*) and (*d*) were inoculated on April 21st with drops of water containing conidia, each leaf at five places on the upper surface on one side of the midrib, a corresponding number of drops of sterile water being placed on the other side of the midrib as controls. Five leaves on plant (*c*) and four on (*d*) were inoculated in this way.

On April 26th more than half the inoculated places were showing as pale yellowish areas 1–2 mm. in diameter, grey in the centre. On one leaf all the five spots were clearly seen. By April 30th thirty out of the forty-five inoculations had produced infection spots up to 6 mm. in diameter. Sometimes the margin of the leaf was curling upwards in the infected half. The control half of every leaf showed no signs of infection.

The results of these experiments summarised are:

Mycelium placed on punctures	37 infections out of 46 inoculations
Mycelium placed on spots not punctured	6 infections out of 6 inoculations
Conidia (taken from infected spots on leaves) applied in drops of water without wounding	126 infections out of 189 inoculations

Summary.

Inoculation experiments have shown that the fungus *C. cantuariensis* Salm. and Worm., found in 1922 associated with a leaf-spot of hop plants in a commercial hop garden at Canterbury, is the primary cause of the disease. Under experimental conditions infection could be induced by means of inoculations with mycelium from plate cultures or with conidia from infection spots. Conidia, placed on leaves of hop plants in moist air, infected the leaves directly and typical spots appeared within a few days. Severe infection sometimes caused premature leaf-fall.

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DESCRIPTION OF PLATE I.

Fig. 1. A hop leaf sixteen days after inoculation at three points with conidia of *Cercospora cantuariensis* (see Experiment 6).
Fig. 2. A hop leaf nine days after inoculation with conidia. Five points were inoculated to the right of the midrib (see Experiment 7).

ON RHIZOCTONIA BATATICOLA (TAUB.) BUTLER AS A CAUSE OF ROOT DISEASE IN THE TROPICS.

(With Plates II, III.)

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(1) Introduction.

Attention has been drawn recently to *Rhizoctonia bataticola* as a parasite of adult woody plants (18, 20). The writer has had the unique opportunity of studying its occurrences in the widely separated regions of Uganda and Ceylon, and therefore gives this account of the extended distribution of the fungus, its enlarged host-range, and the conditions of its occurrence in Ceylon as far as they have been investigated. All the present records of *R. bataticola* are new for Ceylon, and the majority of them for other parts. Inoculation experiments have been planned and undertaken to throw light upon certain obscure points in the parasitism of *R. bataticola* and other root fungi, but as the results are not yet available, there is a certain amount of conjecture which is unavoidable at the moment. Certain facts, however, are recorded, and, as they have led me to more or less unorthodox ideas on the causation of root disease in Ceylon, it is hoped that they will prove of interest. The enlarged distribution and host-range of the fungus and the conditions of its occurrence, particularly on woody plants, may prove to have a significance which extends beyond the two regions in which its parasitism on woody plants has been investigated. The presence of *R. bataticola* seems to explain certain pathological conditions of certain Ceylon plants that have been obscure or misunderstood, for example, the gummosis and dieback of citrus, *Grevillea* and *Acacia*, and the finding and study of *R. bataticola* in regions where it has not yet been recorded may help to solve local problems in a similar way. A thorough search for *R. bataticola* throughout the tropics and sub-tropics, particularly in tea, citrus, cacao and rubber-growing areas, would probably extend greatly the distribution and host-range of the fungus and lead to a full recognition of its suspected great economic importance.

It seems advisable to summarise certain recent work on *R. bataticola* in order to make clear its reported position as a plant pathogen and certain changes of aspect that have entered into its investigation whereby attention has been diverted from herbaceous to woody host plants.

(2) Recent work on *Rhizoctonia bataticola*.

Before 1912 Shaw had studied two Rhizoctonias in India, one of which was characterised by its formation of small black sclerotia (15) and which attacked jute, cotton seedlings, groundnut, cowpea, potato tubers and the mulberry. This fungus Shaw identified erroneously as *R. Solani* Kühn. He proved it to be parasitic on jute, cotton seedlings, groundnut and cowpea, but no further mention was made of its woody host, the mulberry. Taubenhaus had been working meanwhile on the storage rots of sweet potatoes in the United States of America, and in 1913 he published an account of a fungus (23), the effect of which upon sweet potato tubers was to change the healthy flesh into a blackened rotted mass resembling charcoal in appearance and composed largely of the minute black sclerotia of the fungus. He therefore called the rot "charcoal rot," and he named the causal fungus *Sclerotium bataticola*. In 1917 Martin (9) gave an account of a disease of the fruits of chillies (*Capsicum annuum* L.) which he attributed to *S. bataticola*. This disease was regarded as of minor importance, but, in the course of his work, Martin successfully inoculated chilli, sweet potato, tomato, cucumber, apple, eggplant and turnip with the fungus. It is not clear from his account whether the inoculations were carried out on roots, stems or fruits, or on all these parts, of each tested host plant, though inoculations were made through wounds on chilli roots and stems. Martin observed that "death of the plant or plant-part resulted before the mycelium had advanced far from the point of inoculation." His results therefore attributed a certain degree of parasitism to *S. bataticola*. In a recent publication (1) which lists the fungi recorded to date on economic plants in the United States, *S. bataticola* occurs only twice, its substrata being those just mentioned, sweet potato tubers and chilli fruits, and it is concluded that the fungus has not attracted further or more recent attention in America under the name *S. bataticola*. It is probably regarded there as a common soil saprophyte.

Shaw continued his work on *Rhizoctonia* in India, and in 1915 he and Ajrekar (16) again recorded *R. Solani* and gave it as the cause of diseases of groundnut, papaw, water-melon, jute, *Crotalaria juncea*, giant pumpkin, horse-gram (*Dolichos biflorus*), *D. lablab*, Rangoon bean (*Phaseolus lunatus*), mung bean (*P. radiatus*), *Sesamum indicum*, eggplant, potato and cowpea. It will be noted that the only woody plants in the complete list of Indian hosts were cotton seedlings and mulberry. Butler in 1918 (7) attributed the *Rhizoctonia* diseases of the above Indian plants to *Rhizoctonia* sp. indicating thereby that the

fungus had been incorrectly ascribed to *R. Solani*, a fact which had been pointed out by other workers, particularly in America. He also associated the *Rhizoctonia* with a disease of adult cotton, but the fungus had not been shown by experiment to cause the disease and Butler was doubtful of its ability to do so unaided. Shaw published in 1924 (17) an account of an Indian disease of jute with which was associated a pycnidial fungus, *Macrophoma Corchori* Saw. which had been described and named by Sawada, a Japanese worker in Formosa, in 1916, and also the small black sclerotia of "*Rhizoctonia Solani*" which Shaw finally named *S. bataticola*. Shaw showed that the *Macrophoma* was a pycnidial stage of the sclerotial fungus. He also said that a certain proportion of the wilting of mature cotton plants appeared to be due to the sclerotial form of the fungus, *i.e. R. bataticola*.

Meanwhile *R. bataticola* had been attracting attention in Africa. During 1920–22 Briton-Jones (4) had found in Egypt that a *Rhizoctonia* with small black sclerotia attacked cotton, beans, and *Vigna sinensis* and had proved its parasitism on beans, *Vigna* and *Hibiscus esculentus* by soil inoculations. He also considered that the fungus caused a root disease of adult cotton under certain conditions. Briton-Jones's fungus was compared at the Imperial Bureau of Mycology with Taubenhaus's *S. bataticola* and found to be identical with it. Butler considered that the fungus should be regarded as *Rhizoctonia* and made the combination *R. bataticola* (Taub.) Butl. (4). It is to be noted that, up to this point, the host plants of *Rhizoctonia bataticola* were, with two exceptions, herbaceous, and further, that its parasitism was proved for herbaceous plants only.

In 1924 an account was published (18) of a root disease of *Grevillea robusta*, *Bixa orellana*, tea, *Coffea robusta* and *Casuarina equisetifolia* in Uganda. The fungus associated with the disease was characterised by small black sclerotia and also by black lines in the wood and bark of affected roots. The lines were found to be sheets of fungus tissue which had a definite structure and which pursued an irregular course through their substrata and appeared in section as thin wavy plates which in places doubled upon themselves and formed islands after the well-known manner of *Ustulina* lines: they were termed "sclerotial plates," and a connection between them and the sclerotia was established in cultures started from the plates. The presence of small black sclerotia might have suggested the possible identity of this fungus with *S. bataticola* and the *Rhizoctonia* sp., but it was considered to be a new species and was named *R. lamellifera*. An imperfect hymenophore of this form was found on *Grevillea robusta* and was duly described. In 1924, I encountered in

Uganda a wilt of French beans (*Phaseolus vulgaris* L.) with which was associated a fungus with small black sclerotia (19). The fungus was proved to cause a slow wilt of French beans through soil inoculations, and was identified as *S. bataticola*. Along with *Rhizoctonia* sp. from India and Briton-Jones's isolation from Egypt, it was proved to cause Taubenhaus's charcoal rot of sweet potato tubers. In the meantime, the supposed new species, *R. lamellifera*, was discovered on woody hosts other than the original five, and cultural work showed it to be indistinguishable from the *S. bataticola* of the French bean wilt. The name *R. lamellifera*, therefore, had to be abandoned, and, Butler's new combination being unknown to me, *S. bataticola* was adopted (20). At this point the Uganda hosts of the *Rhizoctonia* numbered about twenty. The presence of the sclerotial plates and their relationship to the small black sclerotia were not observed or reported until the study of woody hosts was taken up; in all likelihood, the plates or lines are confined to woody substrata. They are of frequent occurrence on all the woody hosts in Ceylon.

Subsequently, additions were made to the Uganda list of hosts (21), the *Rhizoctonia* being associated with disease of cotton seedlings, *Sesamum indicum*, lupin bean, Damascus bean (*Vicia* sp.), horse-gram and a field-pea (*Pisum arvense*). The full list of the Uganda hosts is given later in this paper. The *Macrophoma* stage was not known from Uganda material until recently when it was found on examination of *Sesamum* at the Imperial Bureau of Mycology. The development of the Uganda fungus is thus on a par with that of the Indian form on jute.

Preliminary experiments with woody seedlings in Uganda to test the parasitism of *R. bataticola* yielded only a few results. A *Eucalyptus* seedling was infected and killed by a strain of the *Rhizoctonia* isolated from coffee, and *Coffea arabica* seedlings by *Sesbania*, *Albizzia* and *Eucalyptus* strains. It has been mentioned already that the fungus caused in experiment a slow wilt of French beans. This wilt differed in its slowness from the rapid collapse of plants in the field, and it was shown that a hot dry spell of weather had more to do with the cause of the wilt than had the fungus. Similarly, it was suspected that environmental conditions were at fault in the cases of an imported vetch, beans, field-pea and horse-gram. In other words, *R. bataticola* did not seem to be strongly parasitic on either herbaceous plants or the seedlings of woody trees, and it may be added that the Indian and other work already mentioned did not show the fungus to be definitely parasitic on woody plants.

On the other hand, the Uganda evidence from the field

implicated *Rhizoctonia* in the deaths of hundreds of full-grown trees, the majority of which were of importance as economic crops like coffee and as shade trees and wind-breaks like *Grevillea robusta, Albizzia* and *Erythrina*. Fortunately, neither *arabica* nor *robusta* coffee proved as susceptible to attack of *Rhizoctonia* as did the other trees mentioned. Although it is likely that it does so, the fungus was not found to attack *Hevea brasiliensis* in Uganda, nor did it spread from one plant to another of the same or a different species although diseased roots were often in prolonged contact with healthy roots. On the whole, it was clear that the majority of the woody victims of *Rhizoctonia* in Uganda did well for five, six or more years before they sickened and died, and it therefore seemed as if the fate of woody plants exposed to the fungus was decided more by their innate immunity or susceptibility, that is, by their powers of resistance, than by their environment. It was possible that the resistance of the plants broke down gradually under continued attack or that the action and progress of the fungus were slow or that environmental factors were at fault, and it was suggested that susceptibility and immunity to *Rhizoctonia* might be governed by biochemical factors. The fact remained however, that the widely-distributed *Rhizoctonia* was a factor of greater or less, if undetermined, importance in the growing of certain plants because their introduction implied their exposure to the fungus in the soil and often their deaths from *Rhizoctonia* root disease, a condition of affairs which seems to be repeated in Ceylon. It should be emphasised that in Uganda *R. bataticola* was found alone practically in all the specimens of its victims that came under observation and that there was therefore no complicated question of the succession of fungi on diseased roots. Attention may be drawn also to the eventual extension of the host-range of the fungus to include woody as well as herbaceous plants.

(3) *Rhizoctonia bataticola* in Ceylon.

Prior to the writer's investigations *R. bataticola* had been found in Ceylon on two occasions. Bryce (6) isolated it from the roots of plantains (*Musa paradisiaca*) affected by bunchy-top disease, and regarded it as a possible cause of the disease. It was isolated also from a dead tea seedling in 1925, but in neither case was it named specifically or used in experimental work. Neither of the Rhizoctonias mentioned by Petch (12, pp. 197, 202) as occurring on new shoots and roots of tea can be identified with certainty with *R. bataticola*.

(*a*) *Ceylon hosts.*

Notes on the hosts of *R. bataticola* in Ceylon have been published (22) but a short account of them may be given here.

(1) *Camillea theifera* Dyer (Tea). *R. bataticola* has been found on dead and dying tea bushes under varying conditions. Between the beginning of May and the end of September 1926, the number of root diseases of adult tea examined was 263. Of these 146 specimens, that is, over fifty per cent., were clear cases of attack by *R. bataticola* alone; in another sixty-six, *R. bataticola* was accompanied by other fungi (by *Poria* in two cases, by *Fomes lamaoensis* in three, by *Ustulina* in seven, by *Fomes lucidus* in two, by *Rosellinia* in five, by *Polyporus interruptus* and *Diplodia* in one, and by *Diplodia* in forty-six; the remaining fifty-one cases consisted apparently of fifteen of *Poria* disease, one of *Fomes lamaoensis* (brown root disease), eight of *Ustulina*, one of *Rosellinia* and twenty-six of *Diplodia**. *R. bataticola* has also been found on tea in company of wood-rot of the branches and shot-hole borer (*Xyleborus fornicatus* Eichl.), of two species of *Calotermes* (*militaris* Desm. and *dilatatus* Bugn.) which bore into and destroy the tissues of the main stem and other parts of the frame of the bush, and of scavenging termites (*Eutermes* sp.) which follow in the tracks of wood-rot. It was suspected that attacks of *Calotermes* might be induced or even entirely conditioned by the previous attack of *R. bataticola*, but the fungus has been found in only three cases out of ten *Calotermes*-affected bushes examined. Further investigation may alter the temporary conclusion, but, in the meantime, there does not seem to be a strong connection between the fungus and the *Calotermes*. Similarly, there is no proof of a constant relation between the presence of *R. bataticola* on the roots and scavenging termites or shot-hole borer or wood-rot in the aerial parts of the tea bush. Such a relation is feasible, but its invariable existence would imply a far greater amount of root disease than is assumed to be present in the field. Again, sudden deaths of tea bushes after pruning have been shown to be due to *Rhizoctonia* root disease, the presence of which was not suspected until the plants died apparently as the result of pruning.

R. bataticola has been found to kill tea seedlings in nurseries and young plants in new clearings. Sometimes *Rhizoctonia* root disease is accompanied by what has been termed a collar-rot, when the external tissues of the stem for a few inches or less at

* *Poria* = *Poria hypobrunnea* Petch or *P. hypolateritia* Berk. *Ustulina* = *Ustulina zonata* Lév. *Rosellinia* = *Rosellinia arcuata* Petch or *R. bunodes* B. & Br. *Diplodia* = *Botryodiplodia Theobromae* Pat.

the collar are rotted or removed to the wood; the rotted area is often bounded by callus both above and below. If *Rhizoctonia* could always be associated with collar-rot, there would be good reason for suspecting it as the primary cause of the trouble as well as of the deaths of young plants without collar-rot, but certain examples of collar-rot seem to have no connection with fungus attack, nor is it clear that the actual rot of the collar tissues is closely connected with the cause of death. It is probable, therefore, that there is more than one type of collar-rot and more than one cause of it, and also that the collar-rot is entirely a secondary phenomenon. The agent which removes the tissues from the collar may be an insect or insects, and, if that were proved, the name collar-rot should be replaced by the word "girdling." A true seedling collar-rot is supposed to be caused by direct fungus attack or by unsuitable conditions at the surface of the soil, for example, wind damage or over-heating which might lead in turn to fungus attack. The matter requires investigation under Ceylon conditions.

(2) *Erythrina* spp., mostly *E. lithosperma* Bl. (Dadap). *Rhizoctonia* disease of dadaps is common. Usually, *R. bataticola* has occurred alone, but sometimes a *Rosellinia* has been found on the main roots along with the *Rhizoctonia*. It is usually impossible to identify specifically a diseased *Erythrina*; the majority are presumed to be *E. lithosperma*, but only introduced species are concerned. Sometimes the sclerotia have been found in enormous numbers on and in the wood of affected roots.

(3) *Phaseolus vulgaris* L. (Beans). Only once has *Rhizoctonia* disease of beans been encountered; several of the diseased plants had been attacked by the bean fly (*Agromyza phaseoli* Coq.).

(4) *Albizzia moluccana* Miq. *R. bataticola* was particularly partial to this shade tree in Uganda, and the same holds in Ceylon. Many dead Albizzias have been seen in the field, and *Rhizoctonia* has been found on the roots of every tree so far examined. Sclerotia and sclerotial plates can be found in the wood of the roots even when rotting is well advanced and when other fungi and bacteria are present. The fungus also attacks and kills seedlings of this species (Fig. 7).

(5) *Acacia decurrens* Willd. (Common or Black Wattle). Several examples of root disease of *A. decurrens* have been examined and in all *R. bataticola* has been found alone. Sclerotial plates develop very freely in the wood of the roots; they have been found also in the stem wood at the collar. Gumming of the stem accompanies *Rhizoctonia* disease in this and the following species.

(6) *Acacia elata* A. Cunn. (Mountain Hickory). *R. bataticola* occurred alone in one example of root disease of this species.

(7) *Grevillea robusta* A. Cunn. (Silky Oak). The silky oak is very susceptible to *Rhizoctonia* disease in Uganda, and the same holds in Ceylon. *Ustulina* and *Diplodia* have occurred on diseased trees along with *Rhizoctonia*. Stem gumming and degeneration of aerial parts takes place exactly as in Uganda.

(8) *Tephrosia candida* DC. (*Boga medeloa*). *R. bataticola* often attacks and kills *Tephrosia candida*. On attack the aerial parts of the plant were infested with a scale-insect (*Ceroplastodes cajani* Mask.) which, however, does not have fatal effects; when infested parts are removed, healthy new shoots appear in their places provided the roots are not attacked by *Rhizoctonia*.

(9) *Clitoria cajanifolia* Benth. *Diplodia* was found on the upper parts of a *Clitoria* plant in which sclerotia of *Rhizoctonia* were very numerous on the wood of the roots and the collar; in other plants *R. bataticola* occurred alone.

(10) *Juniperus* sp. No other fungus was present with *Rhizoctonia* on the single seedling of this species sent for examination. Sclerotial plates were well developed in the stem.

(11) *Anona muricata* L. (Soursop). Only one specimen of soursop root disease has been examined. Roots which had not been attacked by termites were full of *Rhizoctonia* sclerotia.

(12) *Anona squamosa* L. (Custard Apple). Here an unidentified wood-rotting fungus was present with *Rhizoctonia*.

(13) *Hevea brasiliensis* Müll.-Arg. *R. bataticola* has been often found on the Pará rubber tree. Attention was drawn to a single tree by the appearance of fungus fructifications on the soil near the trunk which proved to be connected with a root which was near the surface; they were identified as *Xylaria*, probably *X. Thwaitesii* Cke. to which a root disease of *Hevea* in Ceylon has been attributed (10). The mycelium of the *Xylaria* covered the exterior of the diseased roots, but the wood of all of them was permeated by *Rhizoctonia*, sclerotia and sclerotial plates being present in quantity. The tree appeared to be in good health, but excavation showed that two-thirds of its roots were diseased. In another case, a group of trees was dying back above ground; their larger roots were healthy when examined in the field, while the laterals had been attacked by *R. bataticola*. Several trees were left for future re-examination to determine what fungi, if any, attacked the roots subsequent to *Rhizoctonia*. After five months *Fomes lignosus*, *F. lamaoensis*, *Diplodia* and *Ustulina* had appeared. The last had caused a collar-rot in several of the *Rhizoctonia*-affected trees, and all four secondary fungi were found together on more than one tree. *R. bataticola* sometimes has been associated with *Sphaerostilbe repens* B. & Br., a fungus which seems able to attack roots growing in damp situations only, with *Fomes lamaoensis*, the fungus of

brown root disease, and with *Ustulina*. In the last the sclerotia of *Rhizoctonia* were very numerous in the wood of large roots, while *Ustulina* was confined to the inner cortical layer in the form of mycelial fans. It had not penetrated the wood or caused a collar-rot, and it was apparently of later origin than the *Rhizoctonia*. One tree which was investigated carefully in the field showed *R. bataticola* in all the smaller roots and in many of the larger laterals in the form of hundreds of sclerotia and numerous sclerotial plates (Figs. 5–6). On the larger roots, *Poria, Fomes lignosus* and *F. lamaoensis* occurred. The remarkable point was that the last three fungi occurred on different roots of a single tree and were confined to the exteriors of roots attacked by *Rhizoctonia*. There seemed to be no doubt that *Rhizoctonia* had killed the roots and that the other fungi were saprophytes. In three other trees, every root up to one and a half inches in diameter was full of sclerotia and lines of *Rhizoctonia*, while many of them showed young strands of mycelium of *Fomes lignosus* on the bark; this being apparently secondary in its attack. A wet-rot resembling that described by Belgrave (3) has been found on only one occasion. The tap-root of the tree was in a soft, pulpy condition while the lateral roots were firm but had been attacked by *Rhizoctonia*. Certain so-called *Fomes* (*lignosus*) patches have been examined, and *R. bataticola* has been shown to be present always.

Rhizoctonia attacks on *Hevea*, tea, and other plants occur as a rule at scattered points throughout a field, but several instances of attack on small groups of *Hevea* trees have been encountered. Here the tops of the trees die back and *Diplodia*, which is regarded as the cause of *Hevea* dieback, may be found to have attacked the dead and dying branches. In the absence of a root examination, a diagnosis of *Diplodia* dieback would be made, but *Diplodia* dieback has been shown in all recent cases in Ceylon to be accompanied by *Rhizoctonia* root disease. The presence of the root disease may prove to be a more rational explanation of the origin of the dieback than the weak parasitism of *Diplodia*, and it is therefore wise to look for root disease, particularly *Rhizoctonia* root disease. Investigation of the roots must proceed beyond the collar and larger laterals of the tree, for *Rhizoctonia* is to be found most readily in the smaller roots. Sclerotia may occur in large numbers among the remains of the cambial and cortical tissues of diseased roots as well as in and on the dry hardened wood.

R. bataticola is probably the cause of, or is associated with, more *Hevea* root disease than so far revealed; in fact, a similar suspicion might be directed towards many of the Ceylon hosts of the fungus.

(14) *Tristania conferta* R. Br. (Queensland Box). A well-grown specimen of this tree of about sixty feet in height died recently, and *R. bataticola* was the only fungus found to have attacked the roots.

(15) *Cupressus macrocarpa* Hartw. (Monterey Cypress). A tree of this species of eight years of age was attacked and killed by *Rhizoctonia*. *C. macrocarpa* was also a Uganda host. The examples of *Rhizoctonia* root disease of *Acacia elata*, *Tristania conferta* and *Cupressus macrocarpa* occurred in the Hakgala Botanic Gardens. The three trees were situated about fifty yards from each other, so that infection must have taken place independently.

(16) *Theobroma Cacao* L. (Cacao). Several consignments of dead cacao trees have been examined. *Rhizoctonia* has been found on many of the specimens and symptoms of its presence on all. *Sphaerostilbe*, *Ustulina* and *Rosellinia* also occur at times on the roots. *Rosellinia* is the commonest of these and is found under the bark of the stems as well as the roots; a *Nectria* and a cankered condition of the stems are common. In a former paper (20) it was remarked that *R. bataticola* was one of the factors to which the degeneration of cacao in Uganda was due; it appears now as a result of a careful study of the Ceylon examples of *Rhizoctonia* disease of cacao that it was of greater importance than was suspected.

(17) *Garden plants*. The plants in question are roses, *Hibiscus rosa-sinensis* L. and *Aralia filicifolia* (hort.), and the specimens were all from one garden. In roses the leaves became yellow and fell; the sclerotia of the fungus were found in the wood and bark of the roots, and no other fungus was present. *Poria* occurred on the *Hibiscus* and *Aralia* specimens in addition to *Rhizoctonia*, an association found also on tea and *Hevea*. Sclerotia and hyphae of *Rhizoctonia* were numerous in the pith of the lower part of the *Aralia* stem.

(18) *Capsicum annuum* L. (Chillies). *R. bataticola* has been found on diseased chilli roots; the sclerotia occur on the hardened wood of the roots. Sometimes *Rhizoctonia* root disease is accompanied by pod disease (*Colletotrichum* or *Gloeosporium* sp.), dieback (*Vermicularia* sp.) and leaf mildew (*Oidium* sp.), and at other times by a collar-rot with which *Sclerotium Rolfsii* Sacc. is associated.

(19) *Ochroma lagopus* Sw. (Corkwood or Balsa). Only one specimen of *Rhizoctonia* disease of this South American and West Indian tree has been examined. A small quantity of *Fomes* mycelium (probably *lignosus*) was present on the bark of a root, the wood of which was hardened typically and full of sclerotia and sclerotial plates.

(20) *Citrus medica* L. var. *acida* Hook. f. (Lime). Examination of a large plot of lime trees which were dying slowly showed that *R. bataticola* had attacked the roots. The large numbers of sclerotia and the disintegration of the root cortical tissues recalled the condition of *Erythrina* and *Eucalyptus* roots after *Rhizoctonia* attack in Uganda. *Diplodia* was present on certain of the roots that had been dead for some time, and *Ustulina* caused a collar-rot in several specimens. The above-ground symptoms of the root disease were a gumming of the stems which resembled that described from other parts and a wither-tip of the branches. A bacterium was isolated from the gummed tissues, but it gave entirely negative results in inoculation tests on leaves and stems of young lime plants. A *Gloeosporium* of the *gloeosporioides* type and *Diplodia* were associated with the wither-tip, but their pathogenicity has not been tested. It is to be noted that *Rhizoctonia* root disease induces a gumming of the stems of *Grevillea robusta, Acacia decurrens, A. elata* and *Eucalyptus* as well as of lime. The attack of *Rhizoctonia* on the limes may have been aided by an unhealthy condition of the roots induced by irrigation, but *Rhizoctonia* root disease of limes has occurred in areas where irrigation was not practised. The presence of *Rhizoctonia* disease is a more satisfactory explanation of the prevalence of wither-tip than the parasitism of species of *Gloeosporium*.

(21) *Citrus aurantium* L. (Orange). Orange trees are killed by *R. bataticola*. They show symptoms similar to those of the lime.

(22) *Coffea robusta* Lind. Only one example of *Rhizoctonia* root disease of this host has been found. The effects and manifestations of the fungus corresponded closely to those observed in Uganda on the same host.

(23) *Musa paradisiaca* L. (Plantain or Banana). *R. bataticola* is one of the causes of plantain root disease in Ceylon. Roots affected by the fungus have a dry hard woody core on which small sclerotia occur. The soft tissue external to the woody core is discoloured in diseased roots, and contains sclerotia in small numbers. It is not known whether the above-ground symptoms of *Rhizoctonia* disease of plantains are clearly distinguishable from those of true bunchy-top which is a disease of insect origin or from those of eelworm disease of the roots (*Heterodera radicicola*), but it is customary to refer locally to *Rhizoctonia* and eelworm-affected material as bunchy-top. If the Australian bunchy-top disease of insect origin is also present, there are in Ceylon three major diseases of plantains besides leaf and fruit troubles of minor importance or secondary origin.

(24) *Lycopersicum esculentum* Mill. (Tomato). The tomato is

attacked and killed by *R. bataticola* in Ceylon. The sclerotia of the fungus occur at times in the pith of the base of the stem.

(25) *Amherstia nobilis* Wall. Only one specimen of *Rhizoctonia* root disease of this host, a young plant of four feet in height, has been found. The sclerotia of the fungus were numerous in the bark and on the wood of the roots of the plant, and the effects of the fungus on the roots were typical. *Rhizoctonia* alone was found on the roots, but *Diplodia* and a species of *Nectria* occurred on the stem and branches.

(*b*) *Conditions of occurrence of* R. bataticola *in Ceylon.*

(1) Attention has been drawn to the fact that *R. bataticola* occurred alone on the roots of the majority of its victims in Uganda; in fact, only *Albizzia moluccana* among seventeen woody hosts provided examples of other fungi in company with *Rhizoctonia*. *Diplodia* was found on occasional roots, and *Ganoderma lucidum* (Leyss.) Karst. (= *Fomes lucidus* (Leyss.) Fr.) and *Polystictus occidentalis* (Kl.) Fr. on stumps. The absence of fungi like *Poria, Ustulina* and *Rosellinia* provided a remarkable contrast to Ceylon conditions, where these fungi are encountered frequently. In Uganda, authentic cases of root disease due to such fungi as *Poria, Fomes lignosus, Ustulina* or *Rosellinia* were unknown to me. An *Ustulina* fructification was found only once, on the stump of an indigenous tree in a district well removed from European cultivation, as was also a single gathering of sporophores of *F. lignosus*. Brown root disease (*Fomes lamaoensis*) of young *Hevea* rubber was met with, but it was so rare that the fungus was of no economic importance. There is therefore no evidence from Uganda which might throw light on the Ceylon cases in which more than one fungus is involved. Many Ceylon examples of *Rhizoctonia* disease, however, are on a par with those of Uganda as regards the presence of a single fungus. In other words, they are clear cases of root disease in which it seems reasonable to attribute the disease to the only fungus present, especially when, as often, that fungus can be shown to have penetrated the host plant in a very thorough manner as in *Rhizoctonia* root disease of tea, dadap, beans, *Acacia decurrens, A. elata, Tristania conferta, Cupressus macrocarpa, Tephrosia candida, Clitoria cajanifolia, Juniperus, Hevea brasiliensis, Theobroma Cacao*, rose, chilli and lime. When only one fungus is concerned in a root disease, the responsibility for the disease ought to be placed upon that fungus. This remark applies to newer forms like *R. bataticola* as well as to older-established forms like *Poria, Ustulina* and others. Nothing is said at this point concerning the conditions of the supposed parasitism of *R. bataticola*, but, even if its parasitism was shown

to depend on a factor outside itself, for example, on an unfavourable physiological condition of the roots of the host plant, the fungus must be regarded still as the ultimate cause of a large amount of root disease in Ceylon. It is as widely distributed in Ceylon soils as it was in Uganda, and the more one investigates root disease in which *R. bataticola* is concerned, either wholly or partially, the more is one impressed with its responsibility for disease. Its host-range in Ceylon is impressive enough. No doubt the case for or against *R. bataticola* would be stronger if experimental proof of its ability or inability to attack older plants in the field were available, and, for that reason, inoculations of adult tea, dadap and *Hevea* have been attempted. It may be noted here that only *Ustulina* and *Diplodia* among the so-called old-established fungi have been tested in inoculation experiments; these were shown to be only weak or wound parasites (13, 2), the former of *Hevea* roots and stems and the latter of *Hevea* stems. Neither investigation was conducted in Ceylon.

(2) Root diseases in which more than one fungus appears to be concerned present a different aspect of the problem of allocating responsibility, and they may be called complicated as opposed to the clear ones like those discussed above. Their number is comparatively large in Ceylon, and they require careful investigation. Experimental attempts to inoculate plants with more than one fungus have been made, but results are not yet available and no guidance is to be derived from that direction. Meanwhile it may be pointed out that a complicated root disease resolves itself into a matter of the succession of fungi that can be solved only by determining which fungus precedes the other in time of attack. Provided a plant is in good health up to the moment of attack, it may be possible, although unlikely, that two root or root and collar or root and stem fungi will attack it at the same moment, and, in the following discussion, it is presumed that this condition holds.

It has been found by examination of artificially infected seedlings and field material that the mode of attack of *R. bataticola* on a plant is invasion of the smallest rootlets. The fungus subsequently travels onwards in the bark and cortex; at times the invasion of the wood appears to be a later stage and at others the fungus seems to advance equally in cortex and wood. The youngest rootlets of adult plants sent to the laboratory for examination are invariably missing, but the small woody roots, and sometimes the larger, show that, on the whole, penetration and formation of sclerotia and sclerotial plates are more advanced in the more distant or youngest parts of the roots. These conditions are not always equally clear, but, generally speaking, they hold for the Ceylon hosts of *R. bataticola*.

Again, it was mentioned in a former paper (20) that *R. bataticola* probably had a toxic action, and a field examination of root disease in which only a proportion of the roots is diseased seems to support the probability. The whole of the aerial part of the tree may be dying back when only a few of its roots are attacked by *Rhizoctonia*. Further, the wood of an attacked root can be found to be dead, dry and typically hardened in advance of the actual progress and penetration of the fungus. In *Grevillea robusta* and other hosts, an extensive deposition of a substance resembling gum in the tissues of the roots and stem and emissions of gum on the bark of the stem can be found at points several feet away from the nearest point reached by the fungus in its progress along a root or roots, and attention may be called to the remark of Martin already quoted, that death took place "before the mycelium had advanced far from the point of inoculation." Whatever the mechanism of the action may be, it is possible that the gradual progress of *R. bataticola* along a root or roots has the effect of killing or weakening in advance the bark and cortex and also the wood of the main roots, the collar and the stem, and of rendering those parts susceptible to the attacks of fungi which are present in the soil or are spread by air-borne spores, particularly those fungi which are not able to attack successfully without a preliminary weakening of their host. *Ustulina*, a fungus which has been proved to be a wound parasite of *Hevea*, is an example, and it is possible that the previous harm wrought by *Rhizoctonia* provides ideal conditions for its entry. The fungi which occur on tea and *Hevea*, for example, along with *R. bataticola*, are supposed to have their points of origin on the larger roots near the base of the stem or on the stem itself just below or at ground level or on the above-ground parts of the plant, and the hypothesis may therefore be advanced that, in complicated cases, the procedure is as sketched above with reference to *Ustulina*. *R. bataticola* may thus be regarded as the primary agent which prepares the way for the other fungi, and it follows that *Ustulina* and the other fungi on tea, *Sphaerostilbe repens*, *Fomes lamaoensis*, *F. lignosus*, *Poria* and *Xylaria Thwaitesii* on *Hevea* and *Rosellinia* and *Ustulina* on cacao, to mention only a few, are secondary.

A fair amount of evidence in support of this hypothesis has been derived from the examination of laboratory and field specimens. *Ustulina*-cum-*Rhizoctonia* disease of tea may show the fungi in equally advanced stages, as far as can be judged in the absence of any scientific basis of comparison, but a specimen has been seen in which the *Ustulina* attack was in an incipient stage at the collar of the plant while the *Rhizoctonia* was well established in the roots. In *Rosellinia*-cum-*Rhizoctonia*

on tea, the wood of roots which have *Rosellinia* mycelium on the bark is found to be literally full of the sclerotia of *Rhizoctonia*. *Poria* causes a soft rot of attacked tea wood while *Rhizoctonia* hardens it and renders it brittle. In *Poria*-cum-*Rhizoctonia* the upper part of the tap-root which was covered with *Poria* mycelium was unaffected by *Poria* rot and still in the hard dry state induced by *Rhizoctonia* attack at a lower point. In *Fomes lamaoensis*-cum-*Rhizoctonia* a number of tea plants growing together were killed by *Rhizoctonia* in all except one in which both *Fomes* and *Rhizoctonia* were present, and, in a similar *Hevea* root disease, the *Fomes* occurred on the exterior of roots which showed in the wood sclerotial plates of, and typical hardening due to, *R. bataticola*. The *Fomes* had not penetrated beyond the bark and cortex. That it might do so was shown by other parts of roots of the same tree which were full of sclerotia of *Rhizoctonia* and at the same time were rotted or honeycombed by the *Fomes*. The conditions in other root diseases of *Hevea* which have been mentioned under a previous heading have a similar bearing on the point under discussion. Those facts support the above hypothesis, but they are insufficient to justify a definite opinion on the subject of priority in time of attack of *R. bataticola* over the other fungi. The question will be enlightened or decided, it is hoped, by the experiments in progress. As results will not be available for some time, perhaps for years, it has been thought advisable to publish the known facts in the meantime.

(3) Concerning root diseases which, like those in the third group under the heading of tea, may be attributed singly to *Poria*, *Fomes lamaoensis*, *F. lignosus*, *Ustulina*, *Rosellinia* or *Diplodia*, I doubt their supposed parasitic status. They have been recorded as the causes of disease of many Ceylon plants (8, 11, 12), and their position as such has seemed to be firmly established. When it is examined, however, it is found to be less firm than it appeared. Attention may be drawn again to the lack of experimental proof of the parasitism of the majority of the fungi and to the fact that those which have been tested were proved to be only weak parasites. Further, it is worthy of note that I have found them only on those parts which have been affected directly or indirectly by the *Rhizoctonia*. In the field this condition is exemplified best on the spreading roots of a tree like *Hevea*, and one of the most striking examples of it showed an early stage of *Fomes lignosus* confined to roots attacked by *R. bataticola*. Again, the parasitism of the fungi has been assumed on the ground that each is in constant sole association with a certain diseased condition, an assumption of their individual parasitism which would be reasonable if there were no possibility of the presence of another factor. The

presence of fungi like *Poria*, *Rosellinia*, *Ustulina* or *Fomes* is seen plainly, but, before the investigator can be certain that he has considered all the possible causal factors of root disease, he must satisfy himself that other fungi are not present. In fact, he must examine not only the larger roots but all the roots of the affected plant or, at least, as many of them as can be produced. An examination which does not include the smaller roots is incomplete and the conclusion based upon it may be wrong, for the smaller and apparently unimportant roots may and do contain another fungus which ought to be taken into account. In every instance examined since particular attention was paid to the point, typical specimens of tea and other root diseases, for example, cacao and *Hevea*—typical in the sense that they were incomplete, most, if not all, of the small roots being lost—have seemed to be clear cases of, say, *Poria*, *Ustulina* and *Fomes* respectively, but, when the matter was pursued by personally supervising the excavation of specimens or by having further material dug up according to instructions, it was found that *R. bataticola* was also present on the *Poria*-, *Ustulina*- and *Fomes*-infested plants. In other words, root diseases which seem to be at first glance clear one-fungus cases are complicated in reality and without exception by the presence of *Rhizoctonia*.

For the present it is neither possible nor desirable to postulate the invariable presence of *R. bataticola* in root diseases in Ceylon or to assert that *Rhizoctonia* is the primary cause of all root disease and that other fungi are always of secondary importance, but the presumed parasitic status of certain root fungi is doubtful. The proved presence of a new factor, whether occasional or frequent, must be taken into account, when it proves to be as frequent as *R. bataticola*. There are legitimate grounds for a reconsideration of previous ideas of the causation of root disease in Ceylon, and in that reconsideration the part played by *R. bataticola* must be recognised.

It may be added that, in the course of many excavations in the field, I have not found the stumps and other sources or jumping-off places of fungi like *Fomes lignosus* and *Poria* which are indicated in the literature nor the contact said to be necessary for the spread of *Fomes lamaoensis* to living roots. These fungi may be distributed by wind-borne spores, but the majority of them, if not all, must be free in the soil when substrata in the form of stumps and rotting timber are not available. An investigation, both quantitative and qualitative if possible, into the fungus flora of tropical soils is much required. If it were extensive and successful enough to disclose the relative frequencies of certain fungi, it might shed at the same time a valuable light upon the cause of root disease.

There has been found in herbarium material a small amount of evidence which supports the hypothesis that present experience of *R. bataticola* is not really new and that past examples of root disease may be discussed and interpreted in the light of present experience. Again, it has been suggested that *R. bataticola* is nothing more nor less than a very common saprophyte, but the fact that it is often the sole cause of root disease and subsequent death is against the theory of its saprophytism. Stress may be laid also on the fact that it is proving to be a more frequent factor in the cause of root disease in Ceylon than any other fungus; in other words, it is more consistent in its presence. It may not always be an aggressive parasite and it may require special conditions unfavourable to its host to enable it to attack and establish itself with success, but it is as worthy an object of blame for the eventual cause of root disease as fungi like *Fomes* and *Poria*. It may well be that *Fomes* and *Poria* and the others are saprophytes which can attack only plants already killed or weakened by the *Rhizoctonia*.

(4) *Rhizoctonia bataticola* in Uganda and Ceylon: a comparison.

Certain points of comparison between *R. bataticola* in Uganda and Ceylon have been mentioned, but attention may be drawn to the similarity of the hosts and even their identity. The parallel columns give the respective lists.

Uganda	Ceylon
Grevillea robusta	*Grevillea robusta*
Camillea theifera	*Camillea theifera*
Theobroma Cacao	*Theobroma Cacao*
Phaseolus vulgaris	*Phaseolus vulgaris*
Albizzia moluccana	*Albizzia moluccana*
A. stipulata	*Acacia decurrens*
Erythrina umbrosa	*A. elata*
E. velutina	*Erythrina* spp.
E. indica	*Tephrosia candida*
Bixa orellana	*Clitoria cajanifolia*
Casuarina equisetifolia	*Anona muricata*
Sesbania sp.	*A. squamosa*
Codiaeum sp.	*Hevea brasiliensis*
Eucalyptus globulus	*Citrus medica* var. *acida*
Coffea arabica	*C. aurantium*
C. robusta	*Coffea robusta*
Cupressus macrocarpa	*Cupressus macrocarpa*
C. Benthami	*Rosa* (hort.)
Callistephus sp.	*Hibiscus rosa-sinensis*
Gossypium sp.	*Aralia filicifolia* (hort.
Sesamum indicum	*Juniperus* sp.
Vicia sp.	*Ochroma lagopus*
Dolichos biflorus	*Tristania conferta*
Pisum arvense	*Musa paradisiaca*
Vetch (from Palestine)	*Lycopersicum esculentum*
Lupin bean	*Capsicum annuum*
	Amherstia nobilis

The manifestations of *Rhizoctonia* disease are similar in Uganda and Ceylon, and in both the hosts are introduced or cultivated plants. The fungus is widely distributed in both countries. Data to show whether it is confined to certain types of soils have not been acquired, and elevation does not seem to have any influence upon its distribution. The planting of certain species implies exposure to the attacks of the fungus and often subsequent disease and death. It shows no restriction of attack and no specialisation, unless in its preference, as far as is known, for dicotyledons. Nevertheless, it has been associated with the plantain and with cypress and juniper, and it is suspected of causing coconut root disease.

A point of contrast between Uganda and Ceylon has been discussed, namely, that *Rhizoctonia* disease in Uganda is less complicated than in Ceylon. This fact would seem to point to a clearer charge of parasitism against *R. bataticola* in Uganda than in Ceylon, but in this colony the fungus appears to be responsible for much disease and much loss.

It has been mentioned that the parasitism of *R. bataticola* on woody plants in Uganda seemed to depend more upon the resistance of the host than upon environmental conditions, and it is apparent that a similar condition holds in part in Ceylon. As in Uganda, many of the woody hosts succumb after years of apparently normal growth. The plant may be able to hold the attacking fungus at bay for a time or it may be able to retard its progress after its entry; in other words, the progress of the fungus may be slow, as it seemed to be in several *Grevillea* trees under observation in Uganda. If so, a promising line of investigation is opened up. In tea in Ceylon, for example, the periodic pruning, not to mention plucking, to which the plant is subjected may have adverse effects on the health of the feeding rootlets and may provide in that way an easy point and means of entry for *R. bataticola*. The fungus may not be able thoroughly to establish itself at the first attempt, but subsequent interferences with the normal processes of the plant may aid its attack and advance in the tissues and lead to its final establishment as a root parasite. It is a remarkable fact that many of the woody hosts of *R. bataticola* in Ceylon are pruned or hacked at intervals, and it is conceivable that the drastic treatment they receive has an influence on the incidence of *Rhizoctonia* disease, *i.e.* the responsibility for disease may be sometimes laid upon the environment. However, there is no ready means of ridding the soil of a fungus so widely distributed as *R. bataticola*, and a physiological study of the conditions under which the host plants become open to attack may lead to other and indirect methods of combating its ravages. There is really required a

study of the physiology of the root systems of tea and other plants with special reference to the influence upon them of conditions of soil moisture, aeration and acidity, to the effects on their roots of the above-ground treatment of the plants, for example, the pruning of tea and hacking of dadaps, and to changes in the reaction or constitution of their cell-sap during periods of growth or recovery after shock, all or any of which studies may throw light upon the reasons for the susceptibility, resistance or immunity of the individual plant or species to root disease in general and *Rhizoctonia* disease in particular. At the same time, attention to the chemical and physical condition of soils in which the *Rhizoctonia* is prevalent might yield valuable data.

(5) Morphological and other notes.

There is often difficulty in detecting the presence of *R. bataticola*, especially when it is accompanied by other fungi. The symptoms have been summarised (20, p. 295), but emphasis may be laid again on the absence of a rot or softening of affected root or other wood and on the fact that the *Rhizoctonia* is to be found often only on and in the more outlying and smaller roots. It has been mentioned that *R. bataticola* attacks *viâ* the rootlets and that the smallest woody roots are then affected by it. The presence of sclerotia and sclerotial plates in the small roots (Figs. 1–5) is a means of identification which frequently is not to be found in the other roots or parts of the diseased plant, and, if the smaller roots are missing from the specimen, that means is not available. The majority of specimens of root disease forwarded for laboratory examination are wrenched from the soil instead of being dug with care and many of the smaller roots, and sometimes all of them, are left behind. Termites also are responsible for their absence. Again, fungi like *Poria* and *Fomes lamaoensis* which have their point of origin about the collar of the plant grow downwards along the various roots in the form of a crust which not only cloaks the presence of *Rhizoctonia* even on the small roots in advanced cases and by causing a rot obscures the common symptom of *Rhizoctonia* attack, namely, the hard dry condition of the root wood, but sometimes also seems to inhibit its onward progress. The rates of growth of *Fomes* and *Poria*, as measured by the speed with which their crust or external mycelium or other manifestation extends along a root, are probably greater than the rate of *R. bataticola* in the opposite direction, and their inhibiting effect may thus take place before the *Rhizoctonia* has progressed much beyond its invasion and occupation of the smallest roots. If this is so, it adds to the difficulty of establishing the presence of the *Rhizoc-*

tonia, but throws light upon certain field conditions. It is possible, of course, that the fungi which attack the plant at the supposed higher points precede the *Rhizoctonia* in time and kill the plant from above downwards, as *Diplodia* is reported to kill *Hevea* in dieback, but stress may be laid on the more natural mode of attack practised by *Rhizoctonia* and to deduce therefrom that the probability of its priority of attack is greater than that of the other fungi. It is to be noted that *Rhizoctonia* interferes at once with a vital function of the plant, the absorption of water and food materials, by virtue of its attack on the feeding roots. Despite evidence from specimens which seems to show clearly that *Poria* and *Fomes lamaoensis*, for example, grow from above downwards, there is a difficulty about the point of attack of these and certain other fungi, that experiments may throw light upon. These remarks apply particularly to tea, cacao and *Hevea* root diseases because they have received more attention than others, and it may be added that the common lack of small roots is of greater consequence than the cloaking action of the other fungi, especially since it often happens that only a small proportion of the roots of a plant is attacked.

Attention has been drawn to the black lines or sclerotial plates formed by *R. bataticola*, and their structure has been described and figured (18, 20). Figs. 3, 4 and 5 show the macroscopic appearance of a line in small roots of tea and *Hevea*. It will be noted that a line may occur in the bark as well as in the wood of a root and that, when it does so, the part in the wood is continuous with the part in the bark and cortex. Lines or plates develop more freely in certain host plants, for example, *Acacia*, than in others, but they have been found in all the woody hosts of the fungus. They are less wavy or reticulated than lines of other origin; they are usually black in colour though at times small portions of a line may be dark-brown rather than black. Lines occur alone or are accompanied by sclerotia as in Figs. 5 and 6. Inasmuch as their microscopic outline and extent varies with the sizes and character of the cells occupied by the elements of the line, they are not sharply defined when examined under the microscope. They have no hyphae in connection with or proceeding from them as distinct from the hyphae composing them, but, in islands formed by lines, as in Fig. 5, a growth of hyphae from the island side of the lines may take place. The result of such a growth is a blackening of the wood of the island which is shown by the shading in the figure; the hyphae of this area are of the same type as the hyphae of the line itself. *Rhizoctonia* lines in root wood may invade starch cells as well as fibres and tracheids.

At times a line or sclerotial plate appears to belong to one of

two types. It may approximate in structure to the sclerotium, that is, it may appear to be composed of a pseudo-parenchymatous mass of cells, or it may be composed of hyphae which are distinguishable from each other. This hyphal type of line or plate probably passes into the sclerotial type by the filling up of the occupied cell-cavities with a dense growth which eventually becomes a sclerotium-like mass. The appearance of a section of a plate, therefore, may vary with its age, but, at the same time, the actual view obtained depends upon the direction of the section made. Owing to the irregular course of most lines, it is difficult to cut sections of them in a given plane, and the description has therefore been confined to sections of the thin black edges presented to the observer. A section across the edge of a line may present a view in which the component hyphae are distinctly viewed in a longitudinal direction (20, Pl. X, fig. 2), or it may show a structure like Fig. 8 which was made across the edge of the line, the view shown being that of the plane or surface of the line owing, no doubt, to its bending on itself (cf. 20, Pl. XVII, fig. 3). The hyphae shown in Fig. 8 are of two types. One is dark-brown, thick-walled and massed together within the cell cavities; the other is more hyaline, thinner-walled and of a greater proportionate breadth and more irregular outline, and also fills the cell cavities; they are probably younger than the darker hyphae. The figure represents a distinct stage in the development of a line or sclerotial plate of *R. bataticola*, and it is also a good example of the appearance presented by a line sectioned in a certain plane. Fig. 2 of the previous paper (20) and Fig. 8 may be said to represent roughly longitudinal and transverse sections respectively of sclerotial plates or lines of *R. bataticola*.

Other root fungi form lines, and, although other lines which occur in the same substratum as the lines of *R. bataticola* are readily distinguishable, on the whole, from them, it has been necessary at times to establish the identity of a line by a microscopic examination.

The line-forming fungi which occur most frequently with *Rhizoctonia* in Ceylon and which may therefore come into consideration are *Ustulina* and *Fomes lamaoensis*. Macroscopically, the lines formed by *Ustulina* and the brown root fungus differ from the lines of *R. bataticola*, the first in their greater thickness, in being double at times instead of single and in their commonest position in the larger roots and the collar of the tree, and the second in their golden-brown colour and the network they may form. The lines of *Fomes lamaoensis*, however, may be black rather than brown, and, if they are also few and straight, a microscopic examination is required to

determine them. Figs. 9 and 10 are drawings of parts of lines of *Ustulina* and *Fomes lamaoensis* respectively, but all sections of *Ustulina* and *Fomes* lines do not present the appearances depicted. Like the lines of *R. bataticola* they are composed of hyphae which fill the lumina of adjacent cells, and they are therefore of similar structure to *Rhizoctonia* lines when all are viewed, as in the figures, from the edge of the line, but the hyphae of the three forms are readily distinguishable from each other. The figures should be compared with the drawing of a *Rhizoctonia* line (20, Pl. XVII, fig. 2). The hyphae of an *Ustulina* line are comparatively thin-walled and broad, and in the mass are not distinct from each other, appearing to be made up of cells rather than of hyphae and to approximate in that way to the structure of the *Rhizoctonia* sclerotium. In this connection, it is interesting to note that Sharples (13, p. 12) attributes to the *Ustulina* line the functions of a sclerotium and that Brooks refers to it as "a kind of sclerotic plate" (5). The hyphae of a *Fomes lamaoensis* line, again, are thick-walled, narrower in proportion to their length and more defined. They are distinguishable, however, from the hyphae of a *Rhizoctonia* plate in the outlines of the cells of the hyphae and the lack of *Rhizoctonia* characteristics such as the marked constrictions at the septa. They may also appear to be swollen irregularly in the more outlying parts of the line. Sharples states (14) that the elements bordering the lines of *Ustulina* are "crowded with hyaline hyphae," but such hyphae have not been seen in Ceylon material. They probably disappear in older specimens while the line itself persists. The origin and development of *Ustulina* and *Fomes* lines have not been studied; the origin of *Rhizoctonia* lines was mentioned in a previous paper (18, p. 156). Lines of *Fomes lamaoensis* have been described as depositions of a gummy substance in the cells of the wood affected by the fungus, but they are composed of hyphae in all preparations examined.

Many roots and stems killed by *R. bataticola* show a greyish staining of the wood in streaks. In a former publication (20, p. 294) a similar staining was attributed to the presence of *Rhizoctonia* mycelium, but it was not asserted that the staining was a regular characteristic of *Rhizoctonia*-invaded wood. It is well known that *Diplodia* causes a similar staining in stem and root wood, and it has been necessary in these investigations to examine closely certain stained tissues to determine the origin of the staining. It has been found that it is more frequently due to *Diplodia* than to *Rhizoctonia*; in fact, a greyish *Rhizoctonia* staining is not only uncommon but also unknown in many of its hosts. The discolouration induced by *Rhizoctonia* is usually brownish.

In nature *Diplodia* mycelium occurs in tangled masses which can be found and examined with ease in longitudinal tangential sections of invaded wood. The larger longitudinally-arranged hyphae measure up to 12μ in breadth, and they can be followed frequently for long distances. Two or more narrower threads often lie closely pressed to each other, and branching is free and frequent. In the mass the hyphae are of a grey or grey-brown colour. Similar long hyphae occur in *Rhizoctonia*, but, as they are scarce in woody tissues, it seems an easy matter to distinguish them from those of *Diplodia*. It is less easy, however, to identify hyphae with *Diplodia* when they appear to have a connection with *Rhizoctonia* sclerotia, as they may when they pass under a sclerotium, but a close examination sometimes shows that the *Diplodia* hyphae in such situations have no organic connection with the other fungus. In all probability they are a later—or earlier—invasion than the *Rhizoctonia*. In medullary-ray tissue, again, for example, in a *Hevea* dieback stem, *Diplodia* mycelium assumes other characteristics. The cells of the hyphae are comparatively short and their shapes and sizes bear a strong resemblance to the shapes and sizes of the cells of *Rhizoctonia* hyphae, as is shown by a comparison of Fig. 14 with Figs. 11–13. Individual cells of hyphae of both fungi are often slightly constricted in the middle of their length and slightly swollen at their ends. *Rhizoctonia* hyphae may be constricted when passing through cell-walls (Fig. 11), but they seldom show the clearly-marked constrictions of *Diplodia* such as are illustrated in Fig. 15. Similarly, the septal constrictions of *Rhizoctonia* hyphae and the triangular-shaped cells often situated at the point where a hypha dichotomises are found in *Diplodia*, but, on the whole, they are less clearly marked than in *Rhizoctonia*. Spherical cells, again, are common in the hyphae of both fungi. The first septum of a branch hypha in *Rhizoctonia* is usually set well back from the parent hypha, and the branch hypha is often typically constricted at its point of origin, but these characteristics are not invariably distinct and they are imitated at times in a lesser degree by *Diplodia*. Lateral papilla-like swellings are common on the cell-walls of the hyphae of both fungi, but they are more typical of *Diplodia* than of *Rhizoctonia*. On the whole, certain hyphae of both fungi show the same irregularities and diversity of cell shape and the same bending and curving and variations in breadths, and at times there has been difficulty in identifying given hyphae. Cultural tests are of value when only one fungus is present, but they are useless when the presence of both *Rhizoctonia* and *Diplodia* is suspected. The growth of *Diplodia* in an artificial medium is more immediate and more rapid than that of *Rhizoctonia*; and,

in fact, only *Diplodia* is found in culture in such cases, but the apparent absence of *Rhizoctonia* in culture is no proof that it was not present in nature. Again, the formation of "gum" induced by *Rhizoctonia* might be used to prove the presence of the fungus, but its occurrence is not sufficiently universal throughout affected tissues. Apart from the sclerotia and sclerotial plates of *Rhizoctonia*, distinguishing characters of value are therefore scarce, but substitutes for them may be found in the colours of the respective hyphae and in their relative persistence in the tissues. *Rhizoctonia* hyphae are brown, pale-brown or almost colourless, while those of *Diplodia*, especially the larger, are grey, grey-brown or yellow-brown. *Rhizoctonia* hyphae do not persist to the same extent as *Diplodia* hyphae; in fact, they seem to disappear when the sclerotia are fully formed in nature as they do in culture when the medium begins to dry. The value of these tests, however, is not constant and they must be applied with caution.

There is little or no difficulty in distinguishing between growths of *Rhizoctonia* and *Diplodia* in culture. They may be distinguished by the presence or absence of the small black sclerotia which develop in enormous numbers in *Rhizoctonia* and by the absence or presence of pycnidia which develop in *Diplodia* and give a characteristic configuration to the surface of the medium. Certain so-called *Rhizoctonia* characters, for example, the position of the first septum of a branch hypha and the dichotomous branching characterised by the presence of septa near the points of origin of both new hyphae, are always well marked in *R. bataticola*, but, as already pointed out with reference to *Diplodia* in nature, these characters occur also in *Diplodia* in artificial culture. In *Diplodia* they are not so frequent or so well marked as in *Rhizoctonia*, and the mode of branching in *Diplodia* hyphae is shown by the position of the septum on one of the branch hyphae to be more often a modification of the usual perpendicular mode of branching than a true dichotomy. The same broad hyphae can be found in both fungi and the narrower hyphae of each are of similar dimensions, but the cell-lengths are smaller on the whole in *Rhizoctonia* than in *Diplodia*. Other minute characters, for example, a lateral swelling confined to one end of each of the cells of a hypha, giving the cell a geniculate appearance, are found in both fungi, but the colour of the mycelium of *Rhizoctonia* is always brown whereas that of *Diplodia* is frequently more grey than brown.

Small accumulations of hyphal cells or hyphae may occur in *Diplodia* cultures. They are probably true chlamydospores in their early stages, and, when they are borne on the hyphae which extend over the glass of the culture tube from the edge

of the medium, resemble strongly the sclerotia of *R. bataticola*. When they are young, they have the same oil content as *Rhizoctonia* sclerotia, but, as they become older and larger, they flatten out and then resemble the stromatic or sclerotial masses formed in the medium as a preliminary to pycnidial formation. The presence of such masses in *Diplodia* has been reported by various workers. They are not true sclerotia, but the likeness of their young stages to *Rhizoctonia* sclerotia may be both striking and misleading. Although the likenesses between the mycelia of *Diplodia* and *R. bataticola* and the frequent co-occurrences of the fungi in nature may suggest an affinity between them, there is no proof of such a relation and the morphological resemblances are regarded in the meantime as a coincidence. Mention is made of them in order to draw attention to their existence.

The sclerotia of *R. bataticola* in nature vary in size in Ceylon as in Uganda. The largest Ceylon sclerotia have been found on the surface of the wood of *Hevea* roots where they measure up to ·8 mm. in length by ·6 mm. in breadth. In *Hevea* root bark and cortex, again, the sclerotia are regularly spherical and measure up to 200μ in diameter. On the wood of roots of *Clitoria cajanifolia* they are spherical in shape and average 175μ in diameter, the largest size being 250μ. In chilli plants, the sclerotia in the bark and cortex of the collar average between 50 and 60μ in diameter, while examples have been found in the soft tissue external to the hard woody core of plantain roots which measure only 20μ in diameter. In tea seedlings the sclerotia in the bark of roots are spherical and vary from 64 to 80μ in diameter. The largest in the wood of adult tea roots measure ·45 mm. by ·26 mm.; the smallest length is 170μ and the smallest breadth is 80μ. On the surface of the wood of tea roots they vary in length from 70 to 25μ and in breadth from 45 to 15μ. On the whole, they are more regularly spherical in shape in the tissues external to the wood; in tea wood itself they are longer than they are broad, and examples of only 16μ in breadth have been found to be common.

A large number of strains of *Rhizoctonia* have been grown. They are remarkably similar in development and sclerotial sizes, but a bean strain has sclerotia distinctly smaller and a soursop strain distinctly larger than the average. It is hoped to carry out a biometric study of sclerotial sizes.

Unsuccessful attempts have been made to germinate the sclerotia of *R. bataticola* from tea root material collected in June 1923. The material, however, had been poisoned. There was no difficulty in germinating sclerotia from Bryce's plantain cultures which were dated January 1923 and were four years

old at the time of experiment. In spite of the drying up of the media of the cultures, the sclerotia had a fresh appearance. No success was obtained on agar media, but growth of hyphae from the four-year-old sclerotia took place in four weeks in sweet potato, the method of using which is described below. In view of these results and Taubenhaus's report (23, p. 163) that diseased roots of the sweet potato yielded pure growths of the fungus after one year's dry storage, it is possible that the sclerotia retain their power of germination for a long time. A consideration of the natural distribution of *Rhizoctonia* leads to the conclusion that the sclerotia must remain viable for long periods unless the fungus is capable of continuous growth in the soil or unless new growths of it are being added continually to the soil through the dissemination of the spores of the aerial *Macrophoma* stage of the fungus. It is doubtful, however, if the determination of the longevity of the sclerotia is of immediate practical importance because of the difficulty and expense of making a direct attempt to eradicate the *Rhizoctonia* from the soil of plantations or estates in the tropics.

A simple method of obtaining a pure growth of *R. bataticola* which can be transferred with ease to artificial media has been in use in these investigations. It is useful, in fact, essential, in stubborn cases in which other methods fail to induce growth from sclerotia or sclerotial plates, particularly the latter. It consists of embedding fragments of, say, root wood in sweet potato tuber with the usual precautions. The embedding is done easily by the removal of a wedge of the tuber which is replaced and sealed into position with wax. If the potatoes are dipped twice or thrice in a soft wax after inoculation, they may be left on the laboratory table without further protection. The formation of sclerotia in the flesh of the potato (with the eventual production of Taubenhaus's charcoal rot) requires six to eight weeks or more.

(6) Affinities.

The imperfect hymenophore of *R. bataticola* which was described from Uganda (18, p. 157) has not been found again. An unsuccessful search has been made on woody plant material for the pycnidial or *Macrophoma* stage, but a form which resembled strongly *Macrophoma Corchori* Saw. has been found on the dried stems of chilli plants killed by *Rhizoctonia*. The pycnospores, however, were immature, and their germination was not secured. Pycnidia which occur on *Grevillea* and dadap in Ceylon also resemble those of *Macrophoma Corchori*. Further attention is being devoted to this line of investigation. The writer is informed by Mr S. F. Ashby, Mycologist of the Imperial

Bureau of Mycology, that Sawada's *Macrophoma Corchori* and Petrak's *Macrophomina philippinensis* which was described from *Sesamum* in 1923 are identical and that the correct name of the conidial form of *R. bataticola* is *Macrophomina Phaseoli* (Maubl.) Ashb.*

The pycnidia of *Macrophomina Phaseoli* and certain other pycnidia identical with *Macrophoma Corchori* are not reported to be associated with *R. bataticola* root disease of the plants on which they are found and it therefore appears as if the pycnidium may exist independently, but, in the absence of an examination of the roots of the actual plants bearing the pycnidia, there is a possibility that the pycnidia are accompanied by *Rhizoctonia*. The existence of an aerial pycnidial form which gives rise to sclerotial growths of *R. bataticola* in the soil may explain in part the wide local distribution of the fungus. If it should be shown that the pycnidial stage is found only on plants that are attacked by the root sclerotial form, and only on a proportion of them, it will be justifiable to conclude that, while the pycnidium is responsible for the distribution of the fungus, the soil sclerotial form is of greater significance than the pycnidial form as the immediate cause of plant disease. This point deserves attention.

(7) Experiments in progress.

It has been mentioned that certain inoculation experiments are in progress. It is not proposed to discuss them in full, but it may be said that they include inoculations with both natural and cultural material of *R. bataticola*, *Diplodia*, *Poria*, *Ustulina*, *Rosellinia* and the two species of *Fomes* which have come into consideration in this paper, *lignosus* and *lamaoensis*. The doubt concerning the true parasitism of *Diplodia*, *Poria*, *Ustulina*, *Rosellinia* and *Fomes* is sufficient reason for the inclusion of these fungi in the experiments with a view to the determination of their status. In some experiments contact has been made between the intended host and the different fungi both with and without wounding of the host tissues; in others, contact between host and fungus has not been arranged. The experiments include inoculations on adult plants in the field and on seedlings in small pots and in large concrete drain-pipes, and the plants employed include tea, *Hevea*, dadap, cacao, *Indigofera endecaphylla*, jute, chillies, tobacco, *Sesamum indicum*, lime, orange and coconut. Certain inoculations with more than one fungus, for example, *R. bataticola* and *Poria* or *Fomes* or *Ustulina*, have been performed both at what may be called the *Rhizoctonia* point of the roots (the feeding roots) and at the higher points at which the

* See Trans. Brit. Mycol. Soc. xii (1927), p. 141.

other fungi are supposed to attack. The mixed fungi have been applied together at each point and also separately on the same roots, that is, each fungus at its own point. At the same time, certain plants of each set of inoculations are being mutilated systematically by drastic pruning of their branches or removal of their leaves in order to show whether such treatment will influence infection. In the small pot experiments only *R. bataticola* is concerned and the plants have been grown from seed. The inoculum has been introduced at a certain depth in the pots and so placed that the roots of the young plants are likely to come into contact with it. The inoculum consists for the most part of growths of *R. bataticola* on chopped dadap leaves, a medium on which the fungus forms sclerotia readily. In the *Rhizoctonia* drain-pipe experiments, the plants have also been grown from seed, and the inoculum has consisted of growths of the fungus on sweet potato slices which are mashed in sterile distilled water before being applied to the soil, a method which ensures the introduction to, and even spreading in, the soil of hundreds of sclerotia at any required depth. Material from agar cultures has also been used. Control plants have been set up in every experiment. Further experiments dealing with soil conditions, others designed to modify the physiological activities of plants exposed to attack by *R. bataticola* and others dealing with the supposed toxic action of the fungus have been planned but have not yet been carried out. It is proposed to report the results of the experiments at a later date.

(8) Conclusion.

The writer has been struck, not to say astonished, not only by his discovery of *R. bataticola* on numerous plants in a region to which a considerable amount of mycological work has been devoted but also by the conclusions to which his investigations have led, and he is tempted perhaps to make for *Rhizoctonia* larger claims than are justified in the meantime. There is something to be said, however, for the plea voiced at the beginning of this paper, that a search should be made for woody hosts of *Rhizoctonia* in other parts than Ceylon and Uganda, for, frequently, the above-ground condition of Ceylon plants attacked by *Rhizoctonia* corresponds closely with that described from other regions and attributed to other causes. Possible cases in point are the wither-tip of *Citrus* in the West Indies, Egypt and India, dieback and death of cacao in various parts, and root diseases and *Diplodia* dieback of Para rubber in the East. The true significance of *R. bataticola* in tropical agriculture will be shown best by the results of investigations conducted in as many regions as possible.

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DESCRIPTION OF PLATES II, III.

Plate II

Figs. 1–2. Sclerotia of *Rhizoctonia bataticola* on the wood of tea roots. × 1½.
Figs. 3–4. Sclerotial plates or lines of *R. bataticola* in small tea roots. × 1½.
Figs. 5–6. Sclerotia and sclerotial plates of *R. bataticola* on and in the wood of small and large *Hevea* roots. × 1 and × ½.
Fig. 7. Sclerotial plates of *R. bataticola* in the wood of roots and collar of an *Albizzia* seedling. × ½.
Fig. 8. Sclerotial plate of *R. bataticola* in cacao root wood. × 225.
Fig. 9. *Ustulina* line in cacao root wood. × 225.
Fig. 10. Line of *Fomes lamaoensis* in tea root wood. × 225.

Plate III.

Fig. 11. Sclerotium and hyphae of *R. bataticola* in *Grevillea* wood. × 225.
Fig. 12. Hyphae of *R. bataticola* from the inner surface of the cortex of a *Grevillea* root. × 300.
Fig. 13. Young sclerotium and hyphae of *R. bataticola* in root wood of *Citrus* (lime). × 225.
Fig. 14. Hyphae of *Diplodia* in medullary-ray tissue of *Hevea* stem. × 225.
Fig. 15. *Diplodia* hypha in root of *Clitoria cajanifolia* showing constrictions at points of passage through cell walls. × 300.

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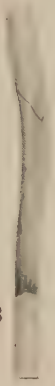
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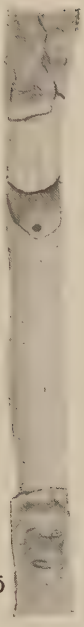
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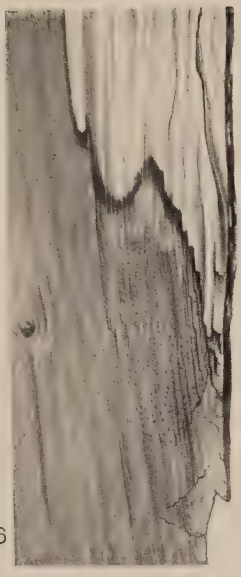
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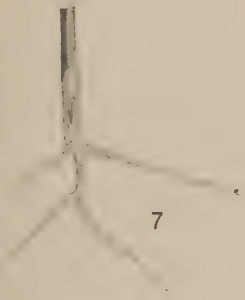
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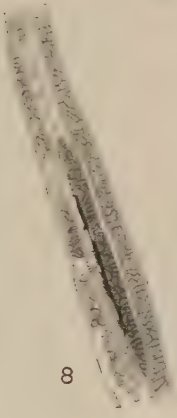
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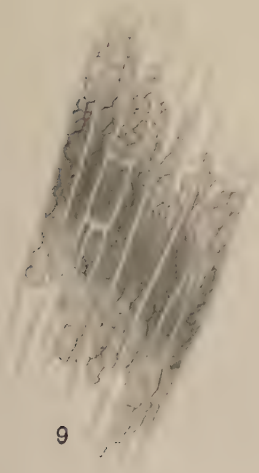
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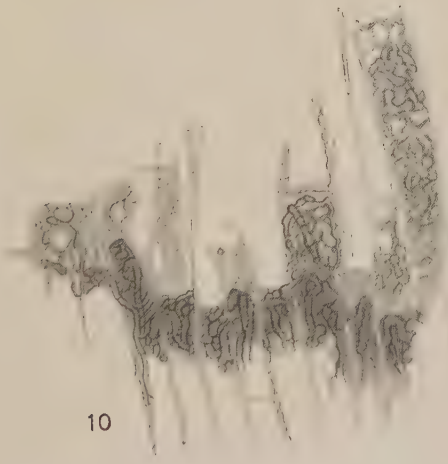
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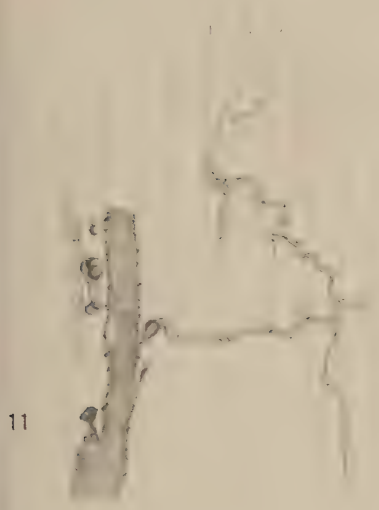

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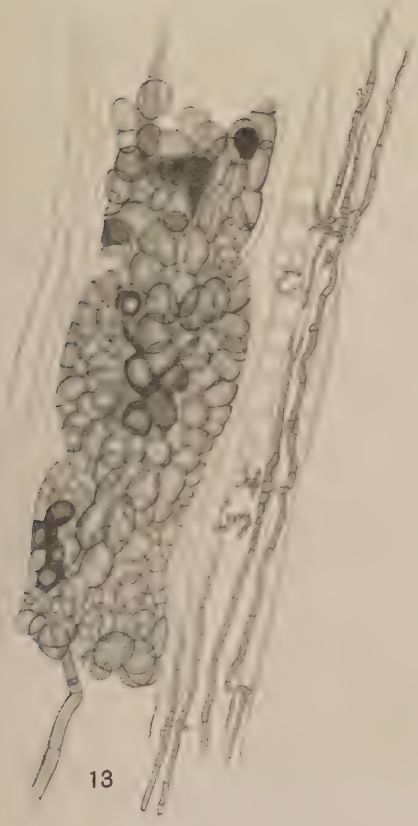

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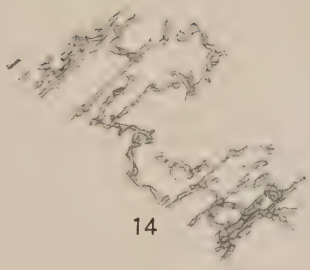

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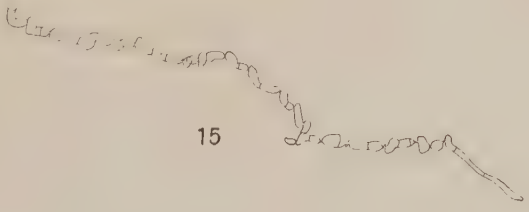

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NEW BRITISH HETEROBASIDIAE.

(With 7 Text-figures.)

By A. A. Pearson, F.L.S.

A NUMBER of species of Heterobasidiae have been found during the last few years many of which have not previously been recorded for this country. Some of these are common and the fact that they are absent from our Fungus floras shows that there has been no serious attempt to look for them. For example, *Heterochaetella crystallina* was first described by the Abbé H. Bourdot in *Trans. Brit. Myc. Soc.* VII, p. 56, but I have seldom visited a pine wood without finding at least one specimen, and sometimes it is abundant on every log in an advanced stage of decay. Similarly with another common species, *Glocotulasnella cystidiophora*, which was first recorded by its author, F. von Hoehnel, in 1906, when revising a Finnish collection of resupinates made by Karsten. This species is to be found in most of the deciduous woods in the south-east of England, and probably would be discovered on old beech or other logs everywhere in Northern Europe.

We have all observed the black, somewhat shiny aspect of prostrate decorticated logs, especially beech logs. This is due, in a large part, to the adnate encrusted film of various species of resupinate Heterobasidiae, more especially of the species just mentioned. That these and other species should have been overlooked is not surprising. They all have much the same appearance; a thin hyaline or grey semi-liquid film that gives little promise of interest. Sometimes they have the appearance of a plasmodium, and doubtless many searchers for mycetozoa have mistaken them for such, only to find them dry up or disappear entirely, instead of producing the expected sporangia. They will often remain fresh for several days in a closed tin.

Grateful thanks are due to Miss E. M. Wakefield and the Rev. Abbé H. Bourdot for their kind and most generous help in the study of this group.

PLATYGLOEA VESTITA Bourd. & Galz. in Bull. Soc. Myc. Fr. XXXIX (1924), 261.

Effused in small patches; fairly thick, muco-gelatinous or sometimes waxy-gelatinous, greyish hyaline, leaving no trace when dry. Hyphae 8–10, flexuose and somewhat torulose. Basidia at first obovate, then cylindrical—club shaped; 40–50 × 6–10μ,

1–3 septate, with conical sterigmata up to 20μ long. Spores sub-lanceolate, depressed on one side, rounded at top, pointed at base, 15–30 × 5–9μ (mostly about 22 × 6μ).

Buckhurst Park, Withyam, Sussex, Feb. and Dec. 1923 and Feb. 1927. On beech sticks among leaves and on old beech logs which had been stacked for firewood. Not common, but locally abundant.

In the original description the authors state that this species had been collected in the winter on *Erica*, *Genista*, *Rubus*, *Quercus*, *Alnus*, etc.

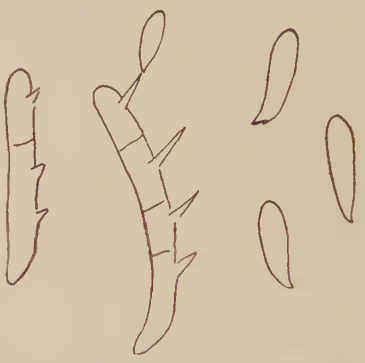

Fig. 1. *Platygloea vestita*. Basidia and spores × 500.

TREMELLA GLACIALIS Bourd. & Galz. *loc. cit.*

Minute, globular hyaline receptacles, looking like white granular sugar or hoar frost under the lens. After a time these

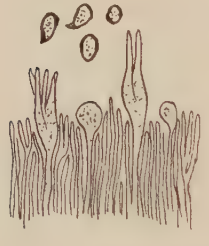

Fig. 2. *Tremella glacialis* × 500.

Fig. 3. *Sebacina subhyalina* × 500.

globose bodies become distorted and coalesce. Hyphae 1–2μ. Basidia ovate, longitudinally septate 7–10 × 5–8μ with 2 or 4 subulate sterigmata 10–20 × 1–1½μ. Spores subglobose or broadly ovate (pip-shaped), pointed at base, depressed on one side 5–8 × 3–6μ (mostly 7 × 5μ).

East Horsley, Surrey, March 1923, on birch logs in advanced stage of decay.

SEBACINA SUBHYALINA Pearson.

Effused in fairly thick patches, indeterminate; surface smooth or with shallow tubercles, rarely almost cerebriform, waxy-

gelatinous, dry in some specimens, usually more or less mucous, hyaline-grey or bluish opaline, drying to a thin black crust. Hyphae branched $1\frac{1}{2}$–2μ. Basidia subglobose, longitudinally septate 8–12 × 8μ with 2–4 sterigmata up to 40 × 2μ flagelliform. Spores slightly curved, cylindrical 7–9 × 4–4·5μ, 1–2 guttulate or granular without guttules.

Found every year since 1920 on old wood (beech, birch, pine, etc.) in Surrey, Sussex, Kent and Worcestershire.

This species has been under consideration for some years, and it is with much hesitation that it is here described as new. It belongs to the series of muco-gelatinous Sebacinae to which various names have been given, chiefly based on the shape and size of spores and basidia.

SEBACINA SUBHYALINA n. sp.

Effusa, mucoso-gelatinosa, v. subceracea, levis, crassiuscula, indeterminata, granuloso-tuberculata v. gyrosa, subhyalina opalea sicco sordide-alba, saepius evanida. Hyphae $1\frac{1}{2}$–2μ ramos gracillimos emittentes. Basidia sub-globosa v. obovata 8–12 × 8μ, 2–4 sterigmatibus flexuosis 25 × 2μ. Sporae subcylindraceae leviter arcuatae 7–9 × 4–4·5μ basi apiculatae.

SEBACINA SPHAEROSPORA Bourd. & Galz. in Bull. Soc. Myc. Fr. XXXIX (1924), 263.

In small patches, or widely effused, with no defined edge, granulose-tuberculous, milky-opalescent, at first gelatinous, then mucose; disappearing when dry, or leaving a dull reddish crust. Hyphae fairly distinct, 1–2μ, branching at the surface. Basidia longitudinally septate, at first globose then ovoid, 8–12 × 6–10μ with 2 or 4 sterigmata. Spores globose, 4–5μ, apiculate, or obovate 4–6 × $3\frac{1}{2}$–$5\frac{1}{2}\mu$.

Coll. E. J. H. Corner, February 1926, at Mildenhall, Suffolk, on old pine log, and June 1926 at Burnham Beeches, Bucks., on rotten beech wood; Epping Forest, Essex, October 1927, on birch, and Harrison's Rocks, near Bridge, Sussex, November 1927, on pine. (A.A.P.)

SEBACINA AMBIGUA Bres. in Fungi Polon. No. 116 (1903).

Effused in patches, muco-gelatinous, tuberculate hyaline then sometimes almost cerebriform, milky opalescent, evanescent when dry. Hyphae 1–3μ. Basidia at first globular, then pyriform 15–17 × 10–12μ with 2 or 3 flagelliform sterigmata which may elongate up to 80μ or more. Spores sub-globose, or broadly elliptical 7–12 × 6–8μ.

Ashdown Forest, Sussex, on burnt wood.

Sebacina (Bourdotia) Galzinii Bres. in Fungi Gall. p. 46.

Widely effused, gelatinous viscid, whitish, opaline, margin the same. Trama formed of agglutinated hyphae which the gloeocystidia traverse perpendicularly; these are mostly narrow tubes, some are wider and flexuose 90–270 × 4–9μ, filled with yellow oily granular contents. Basidia ovoid claviform 16–24 × 8–12μ with the usual flagelliform sterigmata. Spores hyaline, obovate or elliptical depressed on one side mostly 10 × 5μ (10–14 × 5–7½μ).

Coll. E. J. H. Corner. Oct. 1926.

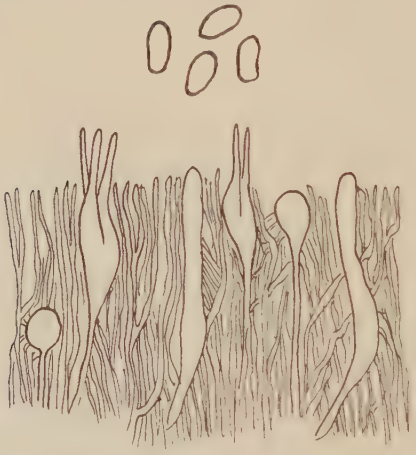

Fig. 4. *Sebacina* (*Bourdotia*) *Galzinii* × 500.

Tulasnella calospora (Boud.) Juel. (*Prototremella calospora* Boud. in Journ. Bot. (1896), p. 85, Fig. *c*.)

Fairly thickly effused in irregular patches; grey with an opalescent tinge, edge the same colour, of a waxy substance, surface woolly under a lens, with the densely crowded long fusoid spores. Hyphae about 3μ septate. Basidia 12 × 9μ with 4 sterigmata, at first ovate, then elongating and narrowing. Spores colourless, fusiform, more or less curved, with granular contents 1 or multiguttulate, about 24 × 4μ (Boudier gives 20–28 × 5–8μ; Bresadola, 26–45 × 4–6μ).

Eridge Park, Sussex, Nov. 1924, under old beech stick lying on ground. (Boudier's record is from rags among rubbish, Paris; Bresadola's on oak wood, Poland.)

Tulasnella sordida Bourd. & Galz. in Bull. Soc. Myc. Fr. xxxix (1924), 265.

Widely effused—in our specimen covering about 20 cm. × 8 cm.—forming a thin waxy-mucose film, smooth or with

shallow tubercles of a pale smoky or faint lilac colour, evanescent or drying to a delicate lilac film. Hyphae 2–7μ, septate, with occasional bulbous swellings, no clamp connections. Basidia

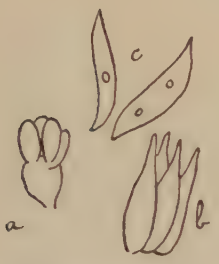

Fig. 5. *Tulasnella calospora*. *a*. Basidium with sterigmata; *b*. sterigmata detached from basidium; *c*. spores. × 500.

Fig. 6. *Tulasnella sordida*. *a*. Spores; *b*. basidia with sterigmata attached; *c*. detached sterigmata; *d*. hyphae. × 500.

obovate, very variable in size 8 × 6μ to 30 × 12μ with 2 or 4 sterigmata, ovate at first 9–10 × 4–5μ then obovate and elongating at the apex 10–15 × 4½–5½μ. Spores broadly ovate, apiculate, filled with dense granular contents, mostly 8 × 6μ (5–12 × 4–8μ).

Eridge Park, Sussex. On a rotten decorticated oak log, one end in ditch. March 1927.

Bourdot and Galzin record it as not infrequently occurring on the rotten wood of many deciduous trees.

Tulasnella (Gloeotulasnella) cystidiophora von Hoehn. & Litsch. Sitz. k. Akad. Wiss. Wien, Math.-nat. Kl. cxv. Abt. 1 (1906), 1557.

Usually in small patches, but often spreading over 30 cm. or more forming a grey mucous film, sometimes colourless, more rarely firm, greyish-blue and waxy-gelatinous. Surface usually with shallow tubercles, sometimes smooth; when dry a black or brown very thin crust. Hyphae 2–4μ colourless, septate. Basidia obovate about 19 × 8μ with 4 ovate sterigmata at first about 8 × 6μ then elongating and narrowing at the apex. Spores sub-globose or ovate apiculate (pip-shaped) 5–7 × 5–6μ with granular contents, colourless, sometimes guttulate. Gloeocystidia with oily yellow contents, very variable in size and shape—bladder, skittle, dumb-bell, etc. The most frequent form is torulose with narrow constrictions—from 10 to 100μ long.

Broadwater Forest, Nov. 1923, Arundel, May 1926, and other

parts of Sussex; Pembury woods, Kent, Jan. 1926; Hereford, Sept. 1926, on beech, birch and oak logs; common on old beech logs during the winter months, after rain when the atmosphere is laden with moisture.

The above description differs from the original one in recording

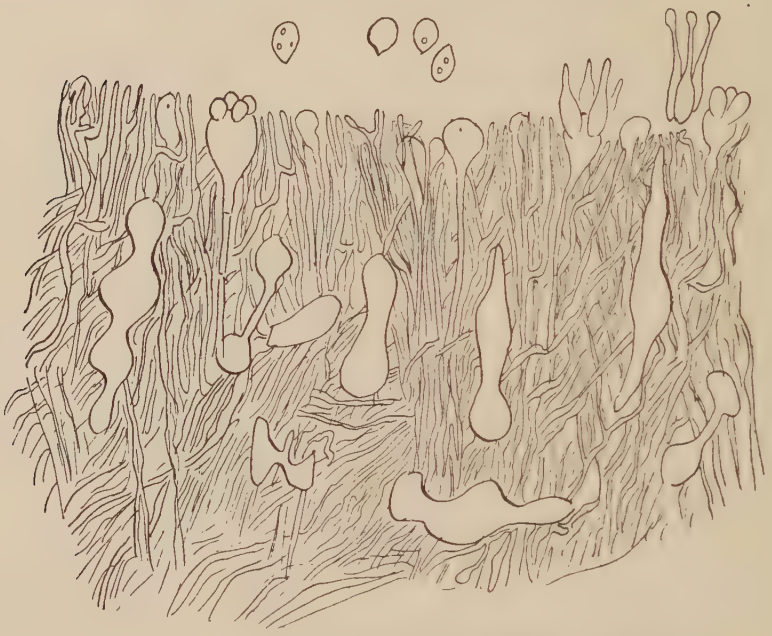

Fig. 7. *Tulasnella* (*Gloeotulasnella*) *cystidiophora* × 500.

the greater irregularity of the gloeocystidia. The original text-figures are club-shaped and flexuose cylindrical. The British specimens invariably have gloeocystidia winding about in all sorts of curious shapes and often with a globose apex. This would suggest that they throw off conidia, but a deposit of spores reveals only colourless basidiospores. Viewed in section (dry) the long sterigmata with spores attached can be seen projecting from the hymenium, but the gloeocystidia are embedded in the mucus and do not project.

ON THE OCCURRENCE OF PHACIDIELLA DISCOLOR (MOUT. & SACC.) POTEBNIA IN ENGLAND.

(With 4 Text-figures.)

By F. T. Brooks.

On the publication of the paper "Notes on a pycnidial fungus associated with a dying-back of apple branches" by Southee and Brooks (1), Miss E. M. Wakefield and Mr W. C. Moore called my attention to a paper by Potebnia (2). Struck by the similarity between the fungus described by Southee and Brooks and that described by Potebnia they suggested that the same organism was perhaps under consideration in both papers. On reading Potebnia's paper it became clear to me that the pycnidial fungus of Southee and Brooks was probably identical with the *Phacidiella discolor* of Potebnia. Experiments were at once commenced to settle the matter.

At about the same time the following cultures were handed over to me for comparative study:

(1) From Dr G. H. Pethybridge a pycnidial fungus (identified as *Fuckelia conspicua* E. & E. Marchal) isolated by Dr R. M. Nattrass from a canker of apple trees in Herefordshire.

(2) From Miss E. M. Wakefield *F. conspicua* E. & E. Marchal from the collection of fungus cultures, Baarn, Holland.

(3) From Miss E. M. Wakefield a sterile culture of *Ph. discolor* (Mout. & Sacc.) Potebnia, originally obtained from Baarn. In spite of all efforts it was impossible to get this fungus to produce spores, so it will not be considered further.

(4) From Miss L. Solberg a culture of "*Pyrenochaeta furfuracea* (Fries) Rostrup" isolated in Norway from a stored apple affected by a black rot. Miss Solberg having previously seen the writer's cultures considered that they were essentially identical with "*Py. furfuracea*," with which she was familiar in Norway.

With regard to *F. conspicua* Dr G. H. Pethybridge received the following information from Monsieur Marchal while in correspondence with him concerning Dr Nattrass' isolation:

> Je crois de voir vous dire que le champignon que mon père et moi avons décrit sous le nom de *Fuckelia conspicua*, avait déjà été recontré par Potebnia qui le considère comme la forme conidienne de son *Phacidiella discolor*.

On commencing this further investigation the writer visited the apple plantation at Meldreth, where the pycnidial fungus was found originally, in order to obtain material from which fresh cultures could be made. Not only were pycnidia again found on

Fig. 1. Ascospore sub-culture on sterilised apple wood, five weeks old. Natural size.

Fig. 2. Ascospore sub-culture on prune agar, two weeks old. Natural size.

Fig. 3. Ascospore sub-culture on Dox's agar, two weeks old. Natural size.

Fig. 4. Sub-culture on Dox's agar of naturally occurring pycnospores, two weeks old. Natural size.

cankered and dying branches of "Lord Derby" trees, but apothecia also, which agreed in every respect with Potebnia's description of *Ph. discolor*.

Cultures from single ascospores and from the junctions of diseased and healthy tissues were established, and the fungi thus isolated were grown on apple wood, Dox's agar and prune agar (used by Potebnia), together with *F. conspicua* and "*Py. furfuracea*" referred to above. The cultural behaviour of all these fungi was essentially the same, and was identical also with that of the fungi described by Southee and Brooks (1) and Potebnia (2).

Photographs of cultures on apple wood, prune agar and Dox's agar are appended (Figs. 1–4).

On apple wood and on prune agar, both in Petri dishes and in tubes, fertile pycnidia were formed abundantly. On Dox's agar in Petri dishes the fungus grew slowly and the mycelium budded profusely in a manner reminiscent of *Dematium pullulans*, as referred to by Potebnia (2); ultimately, however, from the budding mycelium there sometimes grew out hyphae of the type that form pycnidia, as shown in Fig. 4, in which very young pycnidia are just visible near the edge of the dish. On slants of Dox's medium in tubes pycnidial formation occurred more rapidly and more profusely than on plates. A comparison of Figs. 3 and 4 show that the different isolations have considerable differences both in rate and character of growth on Dox's medium in plates.

Potebnia (2) called attention to a peculiar feature of the mycelium on some culture media, in that the walls of certain hyphae become irregularly thickened towards the lumen. This feature was also exhibited by all the isolations now under consideration, being especially clear on prune agar. Potebnia states that Schulz's reagent stains the thickened hyphal walls a pale violet, but in my experience this colour reaction is inconstant.

In Potebnia's account the dimensions of the micro-pycnospores are given as $5 \times 2\mu$, as compared with $3–4 \times 1\mu$ recorded by Southee and Brooks. In some of the recent cultures these spores range from $3{\cdot}8–5 \times 1{\cdot}5–2\mu$. There is clearly considerable variation in the size of these spores. There are a few minor discrepancies between Potebnia's description of these small spores and the findings of the writer. Like Marchal (3), I have not yet got them to germinate, although Potebnia did. The latter states that the micro-pycnospores occur in nature and develop before the larger type of spore. The further experience of the writer agrees with the statement of Southee and Brooks that micro-pycnospores have not yet been found in nature in

England, and that their occurrence in culture is irregular: their formation does not invariably precede that of the macro-pycnospores.

The macro-pycnospores vary considerably in size in the different isolations. The following are some of the measurements recorded in recent work, in comparison with 10–12 × 8μ given by Potebnia, 9·5–12·5 × 6·7–8μ by Marchal (for *F. conspicua*), and 9–14 × 7–10μ by Southee and Brooks:

(*a*) From naturally-occurring pycnidia, March 1927—9–13 × 6–9μ.

(*b*) From culture, from an ascospore, on apple wood—7–12 × 7–9μ.

(*c*) From culture of R. M. Nattrass' isolation of *F. conspicua*, on apple wood—8–15 × 6·8–7·6μ.

(*d*) From culture of the Baarn *F. conspicua*, on apple wood—7·5–15 × 4·5–8μ.

(*e*) From culture of Miss Solberg's isolation of "*Py. furfuracea*," on apple wood—8–12 × 6–10μ.

There is also a certain diversity of shape in these spores: some taper to a point at one extremity, others are nearly spherical, but each strain has a predominant spore form.

The pycnidia vary somewhat in size when cultivated on the same medium: those of "*Py. furfuracea*" on prune agar plates are nearly twice as large as those of the ascospore isolation, although on apple wood they are practically the same.

In spite of the slight differences which have been indicated, all these forms undoubtedly belong to one and the same fungus, *Ph. discolor* (Mout. & Sacc.) Potebnia.

Further evidence of the essential identity of these forms was obtained upon inoculating apple fruits with them. Osterwalder (4) has described a black rot of apples caused by *Ph. discolor*, which is somewhat similar to that often due to *Sclerotinia fructigena*. Miss Solberg informs me that this black rot described by Osterwalder is fairly common in Norway on stored fruits of the variety "Signe Tillisch." Upon inoculating "Bramley Seedling" apples with the various forms described above a black rot was invariably produced. The skin of these fruits became black and the flesh was affected by a brownish-black rot. On apples kept in a moist atmosphere fertile pycnidia developed in great abundance, but with apple fruits kept in a dry atmosphere pycnidia either did not develop or remained rudimentary.

Miss Solberg, who kindly sent the culture of "*Py. furfuracea*" from a black-rotted apple in Norway, had associated this disease in the past with "*Py. furfuracea*" (Fr.) Rostr. on the ground of identity of symptoms and similarity of the pycnidia

with those of "*Py. furfuracea*" described by Rostrup (5) as the cause of a black rot of apples in Denmark. Miss Solberg has kindly sent me the following translation of Rostrup's account of the fungus:

> The fungus attacks apples, which thereby develop a blackened skin in which numerous, close-sitting, fine, flat warts soon appear. In moist air each of these fine points grows into a spherical pycnidium, 0·5–1 mm. across, which is closely beset with fine grey hairs and has a small, shining black, conical ostiole, so that the surface of the apple becomes quite rough. At first the pycnidia have a gelatinous-cartilaginous nature. When ripe the pycnidia become pointed, conical, and contain hyaline, elliptical spores, 8–10 × 4–5μ. The disease is destructive to apples, but appears so rarely that it cannot be said to be of practical importance up to the present.

Rostrup considered that his fungus was identical with *Peziola furfuracea* Fr., described as occurring on rotting pears and apples. Rostrup recognised the peculiar nature of the pycnidia of this fungus, and was unable to assign it to its exact systematic position. There is one considerable difference between *Ph. discolor* and Rostrup's diagnosis of "*Py. furfuracea*," the pycnospores of the latter being only about half the width (8–10 × 4–5μ) of the former. In view, however, of the range of spore size of the various strains of *Ph. discolor* examined, and especially in view of the *average* width of the spores of the Baarn *F. conspicua* being only 5·4μ, perhaps the discrepancy is not serious. Although it has not been possible to examine Rostrup's type specimen of "*Py. furfuracea*," the writer is of the opinion that it is probably identical with the pycnidial stage of *Ph. discolor*. Certainly the fungus sent from Norway belongs to this Ascomycete.

Von Hoehnel (6) states that *Pseudophacidium atroviolaceum* v. H. is the same as *Ph. discolor*. He considers the latter to be the best name for the fungus, but places it in the Stictidaceae instead of the Pseudophacidiaceae as did Potebnia. As regards the pycnidial stage von Hoehnel considers that *Phacidiopycnis* Potebnia = *Discula* Sacc., and that *Phacidiopycnis Malorum* Potebn. = *Cytispora Pyri* Fuck., which he re-names *Discula Pyri* (Fuck.) v. H. On the other hand, Miss E. M. Wakefield, who has examined a Vienna specimen of *Cytispora Pyri* Fuck. in the Kew Herbarium, kindly allows me to state that, in her opinion, this fungus cannot possibly be identical with the one under consideration in this paper as its spores measure 30 × 12μ (20 × 10μ in Fuckel's description). For the present the best name for the pycnidial stage of *Phacidiella discolor* is *Pseudopycnis Malorum* Potebnia.

The writer is indebted to Mr A. K. Briant and Mr E. B. Martyn for much help in the observational and cultural work on this fungus. He would like also to record his grateful thanks

to Miss E. M. Wakefield, Miss L. Solberg, Dr G. H. Pethybridge, Dr R. M. Nattrass and Mr W. C. Moore for cultures and for assistance with literature.

SUMMARY.

The occurrence of *Phacidiella discolor* (Mout. & Sacc.) Potebnia in England is recorded, associated with a die-back and canker of apple trees, as described in a recent paper on the pycnidial stage of this fungus by Southee and Brooks (1). The fungus also causes a black rot of apples in storage.

Cultural work has shown that *F. conspicua* Marchal, and probably also "*Pyrenochaeta furfuracea*" (Fr.) Rostr., is identical with the pycnidial stage of *Ph. discolor*.

Further information is given about the growth of the fungus on culture media.

The synonomy of the fungus is considered.

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SUCCESSIONAL DISEASE IN THE SCOTS PINE.

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IT is now generally recognised that in combating disease, investigation of the predisposing conditions is of great importance, and may even be of as much value as the study of a causal organism, especially so when the diseased plants cannot be readily treated with fungicides either on account of their size or situation or because the cost involved would be greater than the increased value of the crop resulting from such treatment. For the latter reason treatment of diseased trees in the forest with fungicides is rarely or never carried out on a large scale,

although it may be resorted to when it is desired to save a limited number of trees. When it is necessary to check the spread of the disease, destruction of the diseased tree together with the causal fungus is usually the only method possible.

The fact that the predisposing condition for the development of a given disease may be brought about by the previous attack of some other organism is well known, and numerous instances have been described in plant pathology. As an instance of fungal disease following previous attack by another fungus, the infection by *Nectria galligena* of scab wounds produced by *Fusicladium dendriticum* as described by Wiltshire (9) is a particularly interesting example and numerous cases of fungal disease consequent on insect attack have been investigated.

Attacks by a series of parasites in which each organism creates the necessary predisposing conditions for the following one have not been described so frequently, although they are of great interest and often of considerable importance. The expression "successional disease" may be used to describe cases of this kind. Finally, cultural operations, especially if badly carried out, sometimes predispose to certain diseases and here, if disease is to be avoided, the operations must be corrected or modified. It is well known that pruning, especially when performed carelessly, may lead to infection by wound parasites, but it is not generally recognised that bad planting may result in serious disease.

An example of successional disease in Scots pine was recently obtained from Roxburgh in Scotland. The tree, seven years old, is still living, although obviously unhealthy. Some of the current year's needles were green but others were brown and dead and many of the older ones had fallen. On examination it became evident that the tree had been very badly planted for the main root and some of the larger laterals were bent and directed slightly upwards. Even when planting is carefully carried out no doubt some of the roots are killed or injured but here the number affected must have been larger than usual.

Several young fructifications of *Fomes annosus* are present on the bark just at the collar of the tree and investigation of the roots shows that a number of them are infected by the fungus, the wood being discoloured and partially rotted while the tracheids contain numerous fine colourless hyphae. Examination showed that the infection had passed up into the base of the stem but it does not extend much above ground level.

Although there is still some doubt about the exact method of infection by *F. annosus*, Hiley has shown (4, p. 112) that it can attack the tree through wounded and dead roots. It is probable that uninjured living roots cannot become infected.

Planting out, even when carefully performed, probably always brings into existence the necessary predisposing factors for infection, *i.e.* the presence of injured or dead roots, but careless planting by adding to the number of injured roots considerably increases the chances of infection. It has been observed that a tree which becomes infected by *F. annosus* shortly after planting out frequently shows signs of careless planting when dug up. At the present time, when the disease caused by this fungus is becoming increasingly prevalent, it is particularly important that planting should be carried out carefully by skilled workmen. The specimen is also attacked by the beetle *Pityogenes bidentatus**. An account of the genus *Pityogenes* has been given by Fraser (2) who describes the occurrence of *P. bidentatus* in a number of places in Scotland amongst which Roxburgh is not included. The beetle normally occurs on *Pinus sylvestris* but Fraser states that he has never found it on young living trees. Munro (7) states that "at times *P. bidentatus* is harmful in young plantations. The beetles attack the less vigorous plants or young trees in the region of the branch whorls and are able to work in comparatively green and resinous material." This agrees with the present specimen where the galleries extend up the stem to the level of the branch whorls.

There is a general opinion that bark beetles are secondary pests and Hartig (3, p. 17) has pointed out that they often attack plants injured by parasitic fungi. The rather scanty literature on this question has recently been discussed by Munro (7) who quotes the description given by Dufrenoy (1) of an attack of *Armillaria mellea* on maritime pines which was constantly followed by bark beetle attack.

Bark beetles are known to attack trees in which the water content has been diminished. This may be brought about by severe root pruning and late planting, as shown by Munro (7) in an attack on elm by *Scolytus destructor*. The same author (p. 23) also refers to an instance where "*Pityogenes* beetles... attacked some rather large-sized and recently planted Corsican pine which were already weakened by a spell of drought following the planting."

In the present specimen it may be concluded that the attack of *P. bidentatus* has been rendered possible by the low water content of the plant brought about by bad planting and attack by *F. annosus*, as both these latter factors result in death of some of the roots and consequent lowered absorption of water.

* I wish to express my thanks to Dr R. Stewart MacDougall to whom I am indebted for the identification of this beetle.

The specimen has also been attacked by the fungus *Ceratostomella Pini* Münch*, which was previously included in *C. pilifera*, the name given to the group of species which cause the "blueing" of coniferous timber. The blue coloration is evident in the wood when transverse cuts are made in the upper part of the stem. *C. Pini* has been recorded in Britain by Macallum (5) but its life history has not been fully worked out in this country. Münch (6) has given a very full account of the species of *Ceratostomella* which cause "blueing" in Germany and has investigated not only their morphological characters but also the physiological conditions under which infection of the wood occurs. Growth of the mycelium takes place only in wood which contains a certain amount of air; it will not go on in wood saturated with water but, if the amount of water present is diminished, the air content is correspondingly increased and a point is soon reached at which infection will take place. *C. Pini* is often found in the wood of trees which have only recently died and are still standing but apparently has not been found in the wood of living trees under natural conditions. Münch has suggested that the fungus does not grow as a parasite because the living tissues, owing to their high water content, do not contain sufficient oxygen to render the growth of the mycelium possible. He experimented with living trees and found that when the water content of the wood was diminished by chopping through some of the roots, successful infections could be performed and "blueing" resulted in the older sapwood. In another specimen the bark and sapwood were sawn through half way round the stem at two levels, one about eighteen inches above the other, so that the wood between the two cuts was completely isolated from its water supply and in this, as a result of infection, the mycelium spread in the whole of the wood between the cuts.

In the specimen the hyphae of *C. Pini* are present in the wood of the main stem about half way up the tree, and it is suggested that the parasitic habit of the fungus here can be explained by the fact that the normal water supply, and consequently the water content, had been diminished firstly by the bad planting and consequent injury and death of some roots, and secondly by the attack of *F. annosus*, whereby the ascent of sap in the infected roots and in the lower part of the stem was hindered.

* I wish to express my thanks to Mr J. S. L. Waldie who isolated this fungus and grew it in pure culture upon several different media. No perithecia were obtained but numerous conidia of the *Cladosporium* type, typical of *C. Pini*, were produced. No conidia of the *Graphium* type were obtained in any of the numerous cultures made and, on account of this fact, together with the evident coloration of the wood, it may be concluded that the fungus is *Ceratostomella Pini* Münch.

It has been suggested by several investigators that infection of the wood of standing trees by *C. pilifera* may be brought about by the agency of bark beetles. Von Schrenk (8), in the United States, has described trees in attacks of bark-boring beetles associated with the production of "blued" timber. In trees of *Pinus ponderosa* severely attacked by the beetle *Dendroctonus ponderosae*, the blue coloration of the wood seemed to spread from the beetle holes, and it is suggested that the latter form channels for the passage of the hyphae into the deeper layers of the sapwood. In this country, Macallum (5), in the paper already referred to, has noted somewhat similar cases. In these the sapwood of dead but still standing trees of *Pinus sylvestris* was found to be badly attacked by *C. Pini* and *C. Piceae*, and in all observed instances the bark of the trees was riddled by holes made by the pine beetle *Hylesinus piniperda*.

Both the conidia and ascospores of the various species into which *C. pilifera* has been split are more or less mucilaginous and in one of them, *Endoconidiophora caerulescens*, in which the conidia are especially sticky, Münch (6) has suggested that they may be carried by insects. Von Schrenk (8), however, failed to demonstrate the presence of spores of *Ceratostomella* on bark-boring beetles. In the present specimen the blue coloration of the wood is most marked in the vicinity of the galleries of the *Pityogenes* and it appears probable that the infection has been brought about by the agency of the beetle.

In this specimen we have a succession of diseases probably initiated by bad planting. The attack of *F. annosus* was rendered possible by the presence of injured or dead roots resulting from planting; the decrease in the normal water content of the tissues consequent on injury and death of some of the roots due to bad planting and attack by *F. annosus* rendered possible the attack by *P. bidentatus* and *C. Pini* and the infection by the latter fungus was probably brought about by the agency of the beetle.

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THE OOSPORES OF PHYTOPHTHORA NICOTIANAE BR. DE HAAN, WITH NOTES ON THE TAXONOMY OF P. PARASITICA DASTUR.

(With 6 Text-figures.)

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In 1896 Breda de Haan (1) published a detailed account of a serious seed-bed disease of tobacco in the Deli district of Sumatra and at Buitenzorg in Java. He attributed it to an undescribed species of *Phytophthora* to which he gave the name *Phytophthora Nicotianae*. Attempts to obtain growth in pure culture were unsatisfactory and his observations were restricted to the naturally induced lesions on the host and to the growth obtained from fragments of infected host-tissue in water cultures. In such cultures mycelium grew out from the pieces of tissue which developed either zoosporangia alone or sexual organs alone; but he cited one instance in which both kinds of reproductive organs developed. His description indicated that the development of the sexual organs was always definitely of the paragynous type while the zoosporangia were characteristic of a *Phytophthora*. In some instances he found bodies within the host-tissue which he interpreted as oospores. Later investigators, notably Jensen (2) and D'Angremond (3) in Java and Palm and Jochems (4) in Sumatra, all working with pure cultures of the *Phytophthora*, were unable to confirm Breda de Haan's observations on the production of sexual spores, and Palm and Jochems stated in 1924 that oospores were not definitely known in *P. Nicotianae*; they showed also by comparison of cultures and inoculations on tobacco that the species of *Phytophthora* which causes a stem and collar rot and leaf spot of field tobacco in Java was identical with the form causing the seed-bed disease in Sumatra, and that the same strain attacked castor-oil and *Commelina Benghalensis* in nature and tomato following inoculation. Jochems (5) has also reported four species of *Pythium* as the cause of a stem rot of transplanted tobacco in Sumatra; a disease due to one or more of these species of *Pythium* occurs also in the seed-bed with symptoms on stems and leaves indistinguishable from those caused by *P. Nicotianae*. These observations make it seem highly probable that Breda de Haan in his water cultures was not always dealing with the same fungus and that the oospores which developed in water were those of a *Pythium*. Mixed infection moreover might very well account for the occasional development of oospores of a

Pythium and the zoosporangia of a *Phytophthora* in the same water culture.

In 1922 W. B. Tisdale (6) reported on a black-shank disease of shade grown tobacco in Florida as due to a *Phytophthora* which he suspected to be the same species as that on tobacco in the Dutch East Indies and in 1926 he, in collaboration with Kelley (7), published a comprehensive account of the American disease. They compared their *Phytophthora* in pure culture with three cultures of *P. Nicotianae* isolated from tobacco in Java and found them all practically identical in size and shape of sporangia and size of chlamydospores, the only differences being in some slight mycelial characters. Inoculations on young tobacco plants produced identical lesions and all the cultures infected young castor-oil plants, tomato, egg-plant and potato with similar symptoms, the absence of sporangia on the external surface of the diseased organs except in saturated air being also characteristic of all the cultures; chlamydospores were also detected occasionally in the cortex and pith of diseased tobacco stems and it may have been such bodies that Breda de Haan had interpreted as oospores. Tisdale and Kelley concluded that the black-shank *Phytophthora* in Florida could be considered as a strain of *P. Nicotianae*. Neither they nor any of the investigators of the disease in Java and Sumatra subsequent to Breda de Haan were able to detect oospores either in pure cultures or on the host.

Early in 1925, when in Trinidad, I received from Professor W. H. Weston a culture of the black-shank *Phytophthora* isolated by Tisdale in Florida and in 1926 a culture of *P. Nicotianae* from the Centraalbureau, Baarn, Holland, sent there by Rutgers in Java. Zoospore suspensions of the American strain were inoculated on to unwounded leaf blades of young tobacco plants in pots; infection resulted promptly with the production of rapidly enlarging spots quite similar to those which Jensen (8) had described and figured as produced by the East Indian strain. Cultures of both strains on bean-meal agar, quaker oats agar and corn-meal agar behaved alike, forming copious aerial mycelium and sporangia and chlamydospores similar in size, but no sexual spores were detected until a mixed culture was made on corn-meal agar, the inocula being planted about one inch apart on a slant in a tube. The culture was incubated for a few days at 23° C. and then kept in diffused light at the temperature of the laboratory for nine months. A careful search of the whole contents revealed the presence of twenty-three oospores which were found both adjacent to each of the inocula and scattered through the intervening zone. The sexual bodies were dark brown but not opaque, with a thick oogonial wall and

oospores which filled the cavity except at its base. In the majority of them the position of the antheridium could be seen clearly and was in every case definitely amphigynous. The mean size of the oospores was 26·2μ with a range of 22–33μ, while the oogonia showed a mean of 33μ with a range of 29–42μ; the antheridia were approximately 15μ broad by 9μ high and consequently rather shallow. Subsequently oospores were detected in a culture of the Florida black-shank strain on

Fig. 1.

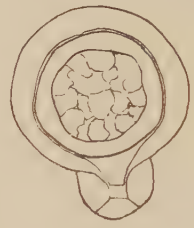

Fig. 2.

Figs. 1 and 2. Oospores in mixed culture of Tobacco strain from Java and Florida. × 700.

quaker oats agar three months old at the temperature of the laboratory; they were present scantily, but seventeen were measured and the antheridium was always definitely amphigynous. The mean size of the oospores was 25·6μ with a range of 20·5–29μ, while the oogonial wall, which was yellowish brown, averaged 30μ in diameter with a range of 25·6–35μ; the antheridia were 12–14μ broad by 7·5–9·5μ high. It would seem, therefore, that *P. Nicotianae*, if retained as an independent species, should be removed from the isolated position assigned to it by Lafferty and Pethybridge (9) on the basis of Breda de Haan's observations as the only known species of the genus with wholly paragynous sexual organs and transferred to the group in which only amphigynous sexual spores are at present known.

In Trinidad a *Phytophthora* was isolated from a black collar rot of a young transplanted wilting tobacco plant and again from a boll rot of Sea Island cotton in the same locality; the two isolations were indistinguishable in culture from the Florida black-shank strain. The isolation from tobacco was inoculated on the leaves of young plants in pots and produced spots which enlarged slowly and did not attain the size of those produced by the Florida black-shank strain. Oospores were either absent or very scantily present in cultures of the two isolations on standard media in the tropical laboratory during two years, but they developed freely after transfer to a cool temperate climate. The oospores had a mean diameter of about 28μ and the antheridia were definitely amphigynous. A strain isolated

from a species of *Pollia* (Commelinaceae) in Sumatra and sent by Dr S. C. J. Jochems to the Imperial Bureau of Mycology has been examined and appears to be indistinguishable from the isolations made from tobacco and cotton. Oospores have not been detected in pure cultures of the *Pollia* strain but large oospores with a mean diameter of 29·4μ and of the amphigynous type were found in its growth-zone after nine months in a mixed culture on corn-meal agar with a strain of *P. parasitica* which, in pure culture on the same medium, developed oospores having a mean diameter of 19μ. A mixture of the Trinidad tobacco strain with the same strain of *P. parasitica* on the same medium and after the same period had also developed oospores of the amphigynous type with a mean diameter of 27·6μ, being similar in size to those produced in pure culture. There can be little

Fig. 3. Oospore near *Pollia* strain inoculum in mixed culture with Tomato strain (*P. terrestris* Sherb.). × 675.

Fig. 4. Oospore near Tomato strain inoculum in mixed culture with *Pollia* strain. × 675.

room for doubting, therefore, that the oospores in the mixture with the *Pollia* strain were actually those of that strain. An isolation by Thompson from bark rot of *Hevea* rubber in Federated Malay States has proved on examination to be quite similar to the other strains but oospores have not, as yet, been detected in its cultures. (This form is a true *Phytophthora* and quite distinct from the species of *Pythium* also isolated by Thompson from bark rot of *Hevea* rubber in Malaya and distinct again from the strain of *P. Faberi* which has been isolated from black-thread disease of *Hevea* in that area.)

These strains with large oospores are practically indistinguishable in the characters of mycelium, sporangia and chlamydospores in cultures on such standard media as bean-meal, quaker oats and corn-meal agars from strains of *P. parasitica* Dast.; in that species, the oospores are smaller, with a mean size not exceeding 19μ, but of the same amphigynous type. Godfrey(10) has, however, referred a form from rhubarb with large oospores of a mean size of 25μ to that species as a variety—*P. parasitica* var. *Rhei*. Tisdale and Kelley compared a strain of *P. parasitica* with the strains from tobacco and could detect

no cultural differences; it also infected tomato, egg-plant and potato with similar symptoms but failed to infect tobacco. I, however, isolated a strain with small oospores and the cultural characters of *P. parasitica* from a collar rot of field tobacco in Jamaica (11). The size of the oospores alone does not appear to be a sound criterion on which to base a difference of species and it is hardly practicable from the standpoint of the plant pathologist, as the sexual spores are often produced with difficulty in cultures, especially of the large-spore strains, and have not been detected on the host. It is proposed, therefore, to eliminate *P. Nicotianae* Br. de Haan and to merge all the strains in *P. parasitica* (12), broadening the conception of that species to cover the group with large oospores; it may be convenient to distinguish the two groups by employing the term "microspora" for that with oospores of a mean diameter of under 20μ and "macrospora" for the group with oospores having a mean diameter exceeding 20μ; these terms have the advantage of not implying restriction to definite hosts.

As emended, *P. parasitica* Dast.* is an omnivorous species of wide distribution ranging from the warm temperate to tropical latitudes with a high optimum temperature for growth (about 30° C. according to Fawcett and Godfrey). In culture on such standard media as bean and oat agars at 25° C., it develops an abundant white lanate and sparingly branched aerial mycelium, becoming matted and tough in tube culture, sterile at first but later forming sporangia scantily or in moderate numbers: the sporangia are typically prominently papillate and broadly ovate, exceeding in the mean 30μ in length and 25μ in breadth with a mean ratio of 1·4 or under; when young aerial growth is transferred to plain water, sporangia are formed abundantly in one to two days with a mean ratio between 1·25 and 1·35. In older cultures, brown, thick-walled, mostly intercalary chlamydospores with a mean diameter of ± 30μ are usually formed in abundance. Sexual organs with amphigynous persistent antheridia are developed in pure cultures at moderate temperatures on standard media either readily and abundantly or late and scantily (the most favourable media are lima or French bean-meal agar and quaker oats agar). The oospores which mostly fill the oogonial cavity range from 12μ to over 35μ in diameter but the range in individual strains is much less; two groups can be distinguished:

1. **Microspora** having oospores of a mean diameter of under 20μ and a range of 12–24μ.

* The strain which Rosenbaum (Journ. Agric. Res. VIII, No. 7, 1917) studied under this binomial with a sporangial ratio of 1 : 1·82 was evidently another species; he was unable to detect oospores in his cultures.

2. **Macrospora**, with oospores of a mean diameter of over 20μ and a range of 20 – ± 35μ (a mean of 25–30μ in the known strains).

If oospores fail to develop in pure culture they may sometimes be obtained by growing two strains together. The group "microspora" would include among others Dastur's (12, 13, 14) strains from *Ricinus communis*, *Vinca rosea* and *Piper Betle* in India, Sherbakoff's (15) strain (*P. terrestris*) from tomato in Florida, Stevens (16) and Fawcett's (17) strains from foot rot of *Citrus* in Florida, etc., Bewley's (18) strain from tomato in England*, a strain from cotton bolls in the West Indies, isolated by Miss Wakefield, and the author's (11) strains from coconut, pineapple and tobacco in Jamaica. There can be little doubt that Sawada's (19) strains from egg-plant and Welsh onion in Formosa belong to this group and that *P. melongenae* and *P. Allii* should be struck out as independent species. The group "macrospora" would include the Dutch East Indian and Florida strain from tobacco, Godfrey's strain from rhubarb (var. *Rhei*) in the United States, the strain from *Pollia* sp. in Sumatra, the author's strain from tobacco and cotton in Trinidad, and probably the strain previously mentioned from *Hevea* rubber in Malaya.

In spite of the broad definition proposed for *P. parasitica* its strains can be readily distinguished in pure culture from the four other tropical and sub-tropical species which possess large papillate sporangia and sexual spores of the amphigynous type, namely, *P. Faberi* Maubl. (more correctly *P. palmivora* Butl.), *P. Colocasiae* Rac., *P. Meadii* McRae, and *P. Arecae* (Colem.) Pethyb. The group of strains comprised under *P. Faberi* (20, 21) has the characteristic in common of developing promptly and in great abundance more narrowly ovate sporangia which when mature fall away from the conidiophores with a short refringent pedicel; sexual spores are not developed in single strain cultures but are formed readily when pairs of appropriate strains are grown in mixture. *P. Colocasiae* (22) produces both broadly ovate and very narrowly ovate sporangia which separate with a long slender pedicel; the zoospores are larger than those of the other species and oospores are developed readily in single strain cultures; a strain of this species has been examined which was isolated by Thompson from *Piper Betle* in Malaya, indicating a wider host range than had been attributed to it. *P. Meadii* (23), which hitherto has been recorded only on *Hevea* rubber in India and Ceylon (and possibly in Burma), forms rather narrowly

* This record of a strain of *P. parasitica* so far north of the normal zone of distribution of the species was apparently due to its introduction in London manure containing plant débris from warm countries.

ovate sporangia (ratio about 1 : 1·6) without a long pedicel, resembling superficially those of some strains of *P. Faberi*, but they are produced more tardily and less abundantly in culture than by that species from which *P. Meadii* differs also by developing oospores in single strain cultures. *P. Arecae* (24) does not appear to differ from *P. Meadii* in any outstanding character; chlamydospores have not been recorded for it, but, as McRae found, these bodies may be absent from cultures of *P. Meadii*; the recorded size of the oospores of *P. Arecae* is somewhat larger than those of *P. Meadii*, which occurs in the same area as *P. Arecae* in South India. Comparative study may indicate that they should be regarded as strains of one species.

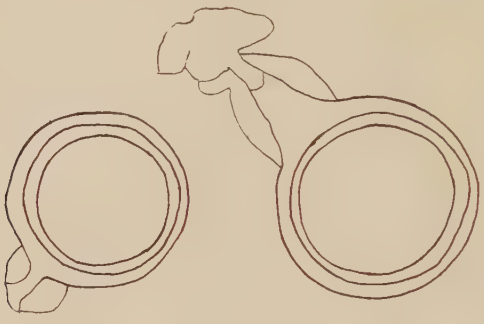

Fig. 5. Fig. 6.

Fig. 5. Oospore of Tobacco strain. Trinidad. × 675.

Fig. 6. Oospore of *P. Cinnamomi* Rands in mixed culture with Tomato strain (*P. terrestris* Sherb.). × 675.

P. Cinnamomi Rands (25), which causes stem rot of *Cinnamomum Burmanni* Bl. in Sumatra, differs from the other tropical species by forming large obpyriform sporangia with no papilla. Chlamydospores are produced in pure culture and in the host tissue but Rands could not detect oospores. However, I found a few large oospores of the amphigynous type adjacent to the inoculum of this species (the culture was obtained from the Type Culture Collection in Chicago) in an old mixed culture on maize-meal agar with the small oospore strain of *P. parasitica* which Sherbakoff had distributed as his *P. terrestris*; the oospores exceeded 30μ in diameter and the one figured (Fig. 6) was 34μ in diameter, exceeding by 10μ the maximum size of the oospores of the strain of *P. parasitica* when grown in pure culture on the same medium.

Leonian (26), largely ignoring morphological characters, has proposed to unite *P. parasitica*, *P. Faberi* and *P. Colocasiae* into one species under the binomial *P. omnivora* de Bary, after

Measurements in microns of the oospores of some strains of P. parasitica.

Strain	Culture medium	Age of culture (months)	No. of oospores measured	Mean diameter of oospores	Range of oospores	Mean diameter of oogonia	Range of oogonia
Section: *Microspora*							
Tomato (*P. terrestris* Sherb.)	Maize-meal agar	1	50	19·2	15·4–22·2	—	—
Tomato (*P. terrestris* Sherb.)	Quaker oats agar	1	50	19·0	13·7–23·9	—	—
Tomato (*P. terrestris* Sherb.)	Bean-meal agar	1	50	15·4*	12·0–19·0	—	—
Coconut, Jamaica	Bean-meal agar	—	50	18·4	14·0–22·0	23·5	18·5–26·0
Pineapple, Jamaica	Bean-meal agar	—	50	17·0	14·5–20·5	23·5	21·0–26·0
Tobacco, Jamaica	Bean-meal agar	—	50	18·5	14·5–20·5	24·5	21·0–26·5
Castor, India. Dastur's data	Bean-meal agar	—	60	18·6	13·0–24·0	23·8	18·0–25·0
Vinca rosea, India. Dastur's data	Bean-meal agar	—	—	15·8	11·0–20·0	—	—
Vinca rosea, India. Dastur's data	Oatmeal agar	—	57	18·4	15·0–23·0	—	—
Egg-plant, Formosa. Sawada's data	Bean-meal agar	—	—	—	17·0–21·0	—	18·0–24·0
Welsh onion, Formosa. Sawada's data	Bean-meal agar	—	—	16·9	14·0–23·0	20·7	17·0–26·0
Section: *Macrospora*							
Tobacco, Java, mixed with tobacco, Florida (*P. Nicotianae*)	Maize-meal agar	9	23	26·2	22·0–33·0	33·0	29·0–42·0
Tobacco, Florida	Quaker oats agar	3	17	25·6	21·0–29·0	30·0	25·6–34·2
Tobacco, Trinidad	Quaker oats agar	3	50	28·6	22·0–37·0	33·0	27·4–42·7
Tobacco, Trinidad, mixed with tomato (*P. terrestris*)	Maize-meal agar	9	50	27·6	21·0–34·0	—	—
Cotton, Trinidad	Maize-meal agar	1	50	27·5	22·0–33·5	—	—
Cotton, Trinidad	Quaker oats agar	1	50	27·8	23·5–34·0	—	—
Cotton, Trinidad	Bean-meal agar	1	50	22·1*	19·7–26·5	—	—
Pollia, Sumatra, mixed with tomato (*P. terrestris*)	Maize-meal agar	9	40	29·4	22·0–34·0	—	—
Rhubarb, United States (var. *Rhei*). Godfrey's data	Oatmeal, bean- and maize-meal agars	—	—	25·0	21·0–30·0	—	24·0–33·0

* In these two cultures on bean-meal agar oospores were formed in very great abundance and many oogonia failed to develop fully and were void of contents; the crowding resulted in a reduction of mean size and range of the oospores.

merging *P. Fagi* Hart. with *P. Cactorum* (Leb. & Cohn.) Schröt. and retaining the last as an independent species. He has assumed that after *P. Cactorum* and *P. Fagi* were separated from *P. omnivora* a residue remained in which some form referable to one or other of the three first-named species could be recognised. Until evidence in support of this view can be furnished *P. omnivora* de Bary must be regarded as a synonym of *P. Cactorum*. In my experience, the morphological characters on which the separation of *P. parasitica*, *P. Faberi* and *P. Colocasiae* as independent species has been based are stable when they are cultivated and maintained on media similar to those which Clinton introduced. The fact demonstrated by Leonian (26, 27) that some strains, such as Godfrey's rhubarb strain of *P. parasitica*, may give rise to stable and unstable morphological saltations when cultivated on saccharine media like malt agar, indicates that such media should be avoided when it is desired to determine the species of a new isolation or to refer it to a sub-group of a known species.

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ADDITIONAL NOTE.

After these notes were written a culture of *P. Nicotianae* recently isolated by Dr S. C. J. Jochems from tobacco in Sumatra became available at the Centraalbureau voor Schimmelcultures, Baarn, Holland. This isolation has been examined and oospores have been found in considerable numbers on bean-meal, quaker oats and maize-meal agars after 3 to 4 weeks' growth at the temperature of the laboratory. Oospores only of the amphigynous type have been detected. The measurements of fifty oospores from each medium yielded the undermentioned results in microns:

	Mean size	Range
Bean-meal agar	20·2	15·4–24·0
Quaker oats agar	23·0	19·0–27·5
Maize-meal agar	24·4	19·0–29·0

The dimensions of the oospores on the quaker oats and maize-meal agars indicate that this strain falls into the section "Macrospora" of *P. parasitica*.

Reference must be made to data recorded in a recent paper by W. C. Lester-Smith entitled "Observations on the oospores of *Phytophthora* species" (*Ann. Roy. Bot. Gdns, Peradeniya, Ceylon*, x, pt. 3, pp. 254–5, 1927). He grew the strain isolated by Tisdale from black-shank of tobacco in duplicate mixed cultures on bean-meal agar with three small-oospore strains of *P. parasitica*. Oospores of the amphigynous type alone, of which 300 were measured, were found in all the cultures after one to two months. The class frequencies showed two maxima, one corresponding to the "mode" of the small-oospore strains in pure culture, and the other, some 4 microns higher, which seemed to be the "mode" of the tobacco strain. It was inferred that the oospores of *P. Nicotianae* on bean-meal agar have a mean size of about 22 microns and a range of 18–25 microns.

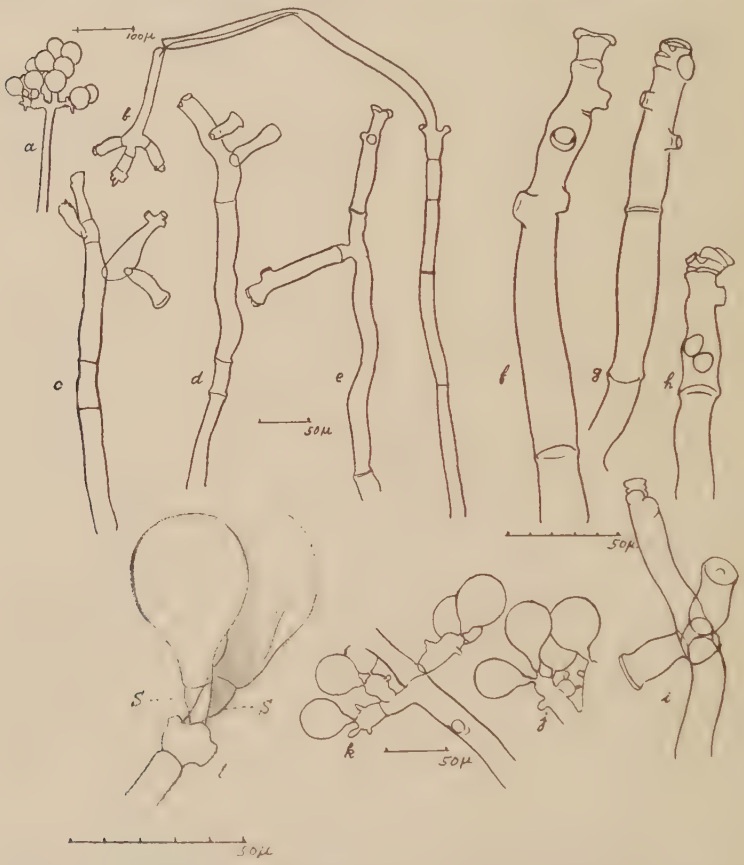
ON AN EXTRAORDINARY BOTRYTIS CAUSING A DISEASE OF NARCISSUS LEAVES.

(With Plate IV and 3 Text-figures.)

By W. J. Dowson.

THE name "fire" has been given by Dr Westerdijk (1, 2) to a disease of narcissus on the continent in which the leaves are attacked from the tip downwards by a species of *Botrytis* of the *cinerea* type; but in the British Isles "fire" disease of narcissus is different as the lesions are not the same and the parasitic fungus concerned is not *B. cinerea*.

A study of the disease in this country has been recently made by me at the Royal Horticultural Society's Gardens, Wisley, and also by Messrs Pethybridge and Moore at the Plant Pathological Laboratory, Ministry of Agriculture and Fisheries, at



Text-fig. 1. *a*, Conidiophore bearing conidia. × 70. *b*, Complete conidiophore from which conidia have fallen. × 70. *c*, *d* and *e*, Conidiophores showing the branched upper portions. × 130. *f*, *g* and *h*, Terminal portions of three conidiophores showing projections and circular markings where branches were attached. × 285. *i*, Terminal portion of conidiophore with branches. × 285. *j* and *k*, Portions of two conidiophores showing attachment of conidia. × 160. *l*, Two young pear-shaped conidia attached to head of conidiophore by sterigmata, *S*. × 460.

Harpenden, to whom I am indebted for observations and for spore-bearing material.

"Fire" disease occurs in the wetter parts of the British Isles and has been found where narcissus is grown in quantity.

Diseased specimens were obtained from South-Western England and from Co. Antrim, North Ireland. Both had identical lesions which formed vivid yellow, elongated blotches on the leaves, generally near the tips, but sometimes lower down. On most leaves only one blotch was present but on a few specimens two were observed. The central portion of the yellow areas was marked by a greyish streak which subsequently turned brown.

When kept slightly damp for a few days the whole of the infected area became brown and finally shrivelled up with the formation of a few smooth, plate-like sclerotia elliptical in outline. Before this happened a few fructifications of a fungus had appeared in lines emerging from the stomata of the central greyish portion. Seen under the microscope the fructifications appeared as small masses of a few large, globular, colourless spores clustered round the summits of branched conidiophores (Text-fig. 1, *a*).

On account of their relatively large size, single-spore cultures were readily obtained by streaking a drop of water containing spores on to plates of ordinary agar with a platinum loop. From these plates the growths arising from single, isolated spores, uncontaminated with bacteria, were removed in a few days and transferred to tubes of different media.

With the pure cultures thus obtained and with the original spores the following inoculations were made. Pieces of healthy green leaves, about two inches long, were cut out from different varieties of narcissus including the narrow, shiny foliage of *N. poeticus* and were placed in damp Petri dishes. Some were laid with the lower surface uppermost, others the reverse way, some were wounded by pricking with a hot needle, while others were untouched. Spores or mycelium deposited on these various surfaces led to rapid penetration of the surrounding and underlying tissues which, in twenty-four hours, became slate coloured. A certain amount of white aerial mycelium appeared and later the elliptical sclerotia, but conidia were not produced.

Leaves still attached to the plant in a greenhouse were then inoculated in the same way and the inocula covered with tin foil. In a few days a yellow discoloration extending beyond the edges of the tin foil was produced on about a third of the inoculated leaves. If left for a few days longer the yellow colour gave place to grey and the leaves finally wilted and became brown all over.

A few of the infected leaves were removed from the plants and kept for a day or two standing in water open to the air of the laboratory. The yellow areas from other infected leaves were cut out and kept in slightly damp Petri dishes.

In both instances after a period of from twenty-four to forty-eight hours conidiophores bearing large globular conidia

were produced in a few scattered lines and were just visible to the unaided eye. The area covered by these fructifications was extremely small and their production lasted only for a few days and then ceased altogether. When examined under the microscope at this stage the conidiophores were seen to have collapsed and were pale brown in colour as were also the detached spores lying on the surface of the leaf. At the place where the conidiophores had emerged from the stomata smooth plate-like sclerotia were slowly formed. A few sclerotia were produced on all the pieces of leaves and were generally elongated bodies which measured from 3 to 6 mm. long by 2 to 3 mm. broad (Text-fig. 3, *q*). On digging up the bulbs some months later it was evident that the foliage only had been infected as no trace of the fungus could be found in any part of the bulb which appeared quite sound. Bulbs having borne infected leaves in Co. Antrim and sent to Wisley for examination were likewise healthy and contained no trace of mycelium or sclerotia. Furthermore, healthy bulbs inoculated with mycelium from pure cultures were found to be uninfected when examined months afterwards

The fungus was grown on Brown's asparagin agar, potato broth agar, artichoke agar (made up like the preceding but with artichoke in place of potato), and steamed plugs of potato and artichoke. Growth on all these was rapid with the production of much white fluffy aerial mycelium. On plate cultures a few sclerotia were produced about the same size but rounder than those formed on the leaves. In tubes of steamed potato and artichoke sclerotia were more numerous and larger, forming contorted masses by the coalescence of many individuals. The difference in size and form of the leaf and Petri dish sclerotia on the one hand, and of the tube sclerotia on the other, may be chiefly attributed to differences in the amount of food and moisture available. Microconidia were produced both in plate and tube cultures and from them also it was found possible to produce normal mycelium when sown in mass in Petri dishes (see below).

Nearly every attempt to remove and mount the conidiophores intact was unsuccessful as the spores fell off on the slightest contact with all the mounting fluids tried, but better results were obtained when young material was available (Text-fig. 1, *l*).

The difficulty was overcome by making use of Klebahn's hanging-drop slides (3)*. Small pieces of spore-bearing material

* *Klebahn's hanging-drop slides.* The basal plate measures 70 × 35 × 2 mm. and the perforated glass slide 48 × 28 × 2 mm. The hole in the centre is 18 mm. in diameter. A cover slip slightly larger than this is placed over the hole and the three parts are sterilised by heat. When cool the cover slip is secured by a ring of melted paraffin wax. The two glass slides are held together by a film of water which can be renewed by placing a drop of water at the angle made by the two slides. Text-fig. 2.

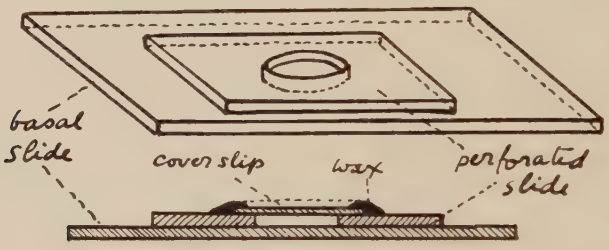
were mounted on the basal plate of these slides and were then covered over with the smaller perforated plate. The necessary moisture was supplied by means of the film of water holding the two slides together. By the use of this arrangement and the camera lucida the drawings shown in Text-fig. 1, *j* and *k* were made. From these it will be seen that the conidia are pear- or balloon-shaped and that a narrow sterigma connects the basal, drawn out portion of the spore with the conidiophore head. At the distal end the conidiophore bears two or more short branches which are also provided with conidia. The sterigmata (Text-fig. 1, *l* and Pl. IV, fig. *r*) are probably very delicate structures which collapse in the process of mounting and so become invisible. If kept for a day or two in the hanging drops, the spores fall off but the sterigmata still remain turgid and after a further twenty-four hours both the conidiophore and the sterigmata commence to grow, the former to make a new branch and the latter to lengthen out into a tangle of fine hyphae.

The conidia as seen detached and mounted in water are balloon-shaped when mature but pear-shaped when first formed. There is a distinct papilla or beak at the smaller end and in some instances the remains of the sterigmata can be seen (Pl. IV, fig. *r*). The conidia vary in size from 30 to 50μ across, but the majority measure about 40μ. When mature they are of a faint brown tint though when newly formed they are colourless. The wall of mature spores is uniformly and relatively thick and the contents appear coarsely granular when seen in water, but in dilute glycerine either numerous small, or a few large vacuoles make their appearance.

The conidiophores are stout structures measuring 1 mm. to 1·5 mm. long by 20μ broad, colourless when young but with a pale brown tint like the conidia when fully mature, except for the extreme distal portion bearing the conidia which remains colourless. They are crooked structures, sometimes much bent, and when mounted appear generally unbranched, although some have a few short branches towards their distal ends (Text-fig. 1, *b*, *c*, *d* and *e*). Here and there septa occur which in glycerine mounts appear to be slightly larger in diameter than the rest of the conidiophore (Text-fig. 1, *g* and *h*) but this may be due to slight shrinkage. Near the ends distinct oval or circular marks (Text-fig. 1, *g* and *h*) can be seen which in profile appear as small projections with smooth rounded ends (Text-fig. 1, *f*). In the branched conidiophores (Text-fig. 1, *e*) at the end of each short branch there is nearly always a septum which corresponds in diameter with that of the oval and circular scars just noted, and it is probable that the latter are the bases of short branches which have fallen off in the process of mounting.

The actual ends or heads of the conidiophores are slightly swollen and bear a small number of sterigmata (Text-fig. 1, *j* and *k*), but in mounted preparations this cannot readily be made out as this portion of the conidiophore seems to be extremely delicate and nearly always collapses in a concertina-like fashion (Text-fig. 1, *h*).

The germination of the conidia was observed in hanging drops of water and agar media mounted on slides as indicated above. In the surprisingly short time of from half to one hour five or six germ tubes began to emerge in a radial manner from the surface of the spore and occasionally the papilla or beak had given rise to a germ tube. After an interval more germ tubes were produced up to generally eight or nine but once thirteen were counted (Pl. IV, figs. *t*, *u* and *v*). Here nine germ tubes were produced at first, then one more appeared which was followed at a short interval by another three.



Text-fig. 2.

Microconidia were produced in abundance in most culture media, and also upon naturally formed sclerotia when kept sufficiently moist. On steamed plugs of potato and artichoke the microconidia became visible as dirty yellow droplets after about two months and arose both from the mycelium and the sclerotia. In hanging drops microconidia began to form after a fortnight and continued to be produced one at a time from the attenuated ends of short lateral hyphae. These were formed in large numbers either from one side of a main hypha (Text-fig. 3, *m* and *n*), or as a cluster on a terminal branch (Text-fig. 3, *p*). When sown in mass on Petri dishes of agar (Dox or Brown) a few of the microconidia germinated to form normal mycelium, but no germination was observed in hanging drops.

A consideration of the structure, mode of growth and particularly the manner of attachment of the conidia seems to warrant the inclusion of this fungus within the genus *Botrytis*, the salient characters of agreement being:

(1) The mycelium is septate and branched, forming woolly aerial hyphae.

(2) The conidiophores are mostly crooked, septate, branched, pale brown when mature and bear sterigmata on a slightly swollen head.

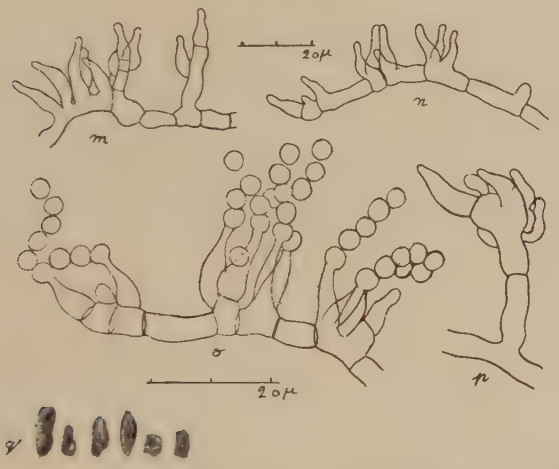
(3) The conidia are globular like those of *Botrytis Ricini*, pale brown when fully formed and attached to the conidiophore by means of sterigmata.

(4) The microconidia agree with those of *Botrytis*.

(5) The sclerotia are of the *Botrytis* type.

On the other hand, the main differences between the genus *Botrytis* and the narcissus fungus are:

(1) The conidia are unusually large averaging 40μ across.



Text-fig. 3. *m* and *n*, Beginning of microconidial production. × 460. *o*, Terminal portion of "*n*" 24 hours later. × 800. *p*, Beginning of microconidial formation as cluster from a terminal hypha. × 800. *q*, Dry sclerotia from dead leaf tissue. × $\frac{2}{3}$.

(2) The production of conidia is very limited and so far as is known takes place only on dead narcissus leaves from which the conidiophores arise from the stomata.

In these respects the present fungus resembles *Botrytis Tulipae* (Lib.) Hopk. which produces abundant conidia upon moribund tulip tissue, but only rarely has it been induced to fructify on synthetic media (4).

(3) An extraordinary number of germ tubes is produced.

As no other *Botrytis* is known with such enormous spores, and as these germinate by the formation of a large number of germ tubes, the name *Botrytis polyblastis*, in allusion to this character, is proposed.

Botrytis polyblastis Dowson, sp. nov.

Maculae flavidae. Caespitula effusa, laxa. Hyphae hyalinae, laxe intertextae, aetate vacuolatae, 3–6μ diametro. Sclerotia in foliis emortuis sparsa, laevia, ellipsoidea, depresso-convexa, 3–6 mm. 2–3 mm. diametro; in vitro majora, rotundata, contorta, saepe confluentia. Conidiophora erecta, flexuosa, vix colorata, superne ramosa; ramuli breviusculi, stipati, apicibus inflatulis hyalinis, sterigmatibus longis praediti, basi stipitellata, cum tunica distincta, 30–50μ diametro, per 8–13 hyphas germinantes. Microconidia globosa, 3–4μ diametro.

In foliis vivis Narcissi, qua enecat.

In conclusion I would like to express my thanks to Miss E. M. Wakefield for the Latin diagnosis and to Mr N. K. Gould for the photomicrograph.

Summary.

The occurrence and appearance of a yellow leaf blotch disease of narcissus found in South-West England and North Ireland and known to growers by the name of "fire" is recorded.

The isolation of a fungus from the blotches and its growth in pure culture is described, and infection experiments indicate that it is pathogenic to the leaves only.

The very large conidia are described in detail and also the microconidia and sclerotia which are of the *Botrytis* type.

Besides the enormous size of the conidia an unusually large number of germ tubes is recorded, and the new species *Botrytis polyblastis* is described.

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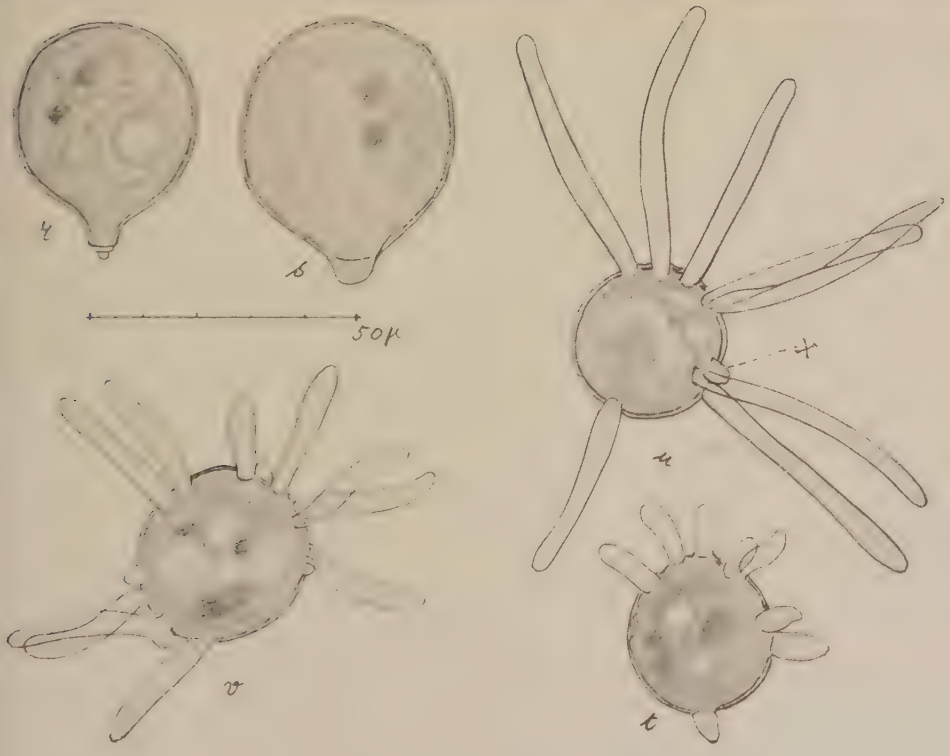
Explanation of Plate IV.

Figs. *r* and *s*. Spores showing wall and granular contents, sometimes vacuolated. × 690.
Fig. *t*. Germinating spore with eight germ tubes after half an hour. × 430.
Fig. *u*. The same spore drawn two hours later. A ninth germ tube has appeared at "X". × 430.
Fig. *v*. Another spore of the same age as that shown in "*u*" with thirteen germ tubes. × 430.
Photomicrograph above of dead leaf tissue showing conidiophores and detached conidia at *A*.



BOTRYTIS POLYBLASTIS DOWS.

COMPARATIVE STUDIES OF KABATIELLA CAULIVORA (KIRCHN.) KARAK. AND COLLETOTRICHUM TRIFOLII BAIN AND ESSARY, TWO FUNGI WHICH CAUSE RED CLOVER ANTHRACNOSE.

By Kathleen Sampson, M.Sc. (Lond.),
University College of Wales, Aberystwyth.

(With Plates V, VI, VII and 6 Text-figures.)

I. Historical.

"Anthracnose" is a popular term applied to certain diseases of plants which present similar external symptoms, notably "burning" and "spotting" of the foliage, caused by fungi having a conidial stage of the *Glocosporium* type. On this basis four anthracnose diseases of red clover (*Trifolium pratense*) have been recorded and attributed to the species—

Gloeosporium Trifolii Peck (31), *G. caulivorum* Kirchner (18), *Colletotrichum Trifolii* Bain and Essary (1, 2), and *C. destructivum* O'Gara (29, 30).

Gloeosporium Trifolii Peck.

This species was recorded first in Albany by C. H. Peck in 1880, the following diagnosis being given:

Gloeosporium Trifolii Peck: Spots sub-orbicular, often concentrically zoned, brown; spores oblong or cylindrical, obtuse, simple, colourless, 0·0006 in. to 0·0009 in. long; 0·00016 in. to 0·00025 in. broad*; living leaves of red clover, *Trifolium pratense*, Albany, July (31).

Further records were made later by E. Rostrup at Askov in Denmark (34, 35, 36) and by A. B. Frank at St Anton in Arlberg, where the host was *T. medium* (11).

A clover anthracnose at Freiberg which Mehner attributed to *G. Trifolii* was evidently *G. caulivorum* and is considered under that species.

Gloeosporium caulivorum Kirchner.

The first diagnosis of this species was given by Kirchner in 1902, who recognised that the disease was the same as that described in the previous year by Mehner. An examination of some of Rostrup's material of *G. Trifolii* Peck from Denmark convinced him, however, that the two diseases were distinct. He gave the following diagnosis:

Gloeosporium caulivorum Kirchn.: Spots small punctiform aggregated or longitudinally elongated, sunken spots of a pale brown colour surmounted by

* 15–22·5 μ × 4–6·

a black rim on living stems of *Trifolium pratense* causing the death of these; conidia unicellular, colourless, curved, sickle-shaped, 12–22 μ long and 3·5–5·2 μ broad (18).

Little additional information has been published on the morphology and physiology of the fungus or the aetiology of the disease but a number of records point to its wide distribution in Europe and its occurrence in the northern States of America. Thus Linhart (20) in a tour through Germany and Bohemia noted the frequent occurrence of *G. caulivorum* in the clover crop and cited instances where the damage was estimated at fifty to sixty per cent. Further severe outbreaks in Bohemia and others in Moravia were described by Baudyš in 1924 (5).

In Holland *G. caulivorum* was first recorded in 1913 and Schoevers gave an account of its distribution and the intensity of the attack on red clover plots of different origins in the following year (38). Miss J. Westerdijk also referred to severe outbreaks particularly in the province of Gröningen (43).

The disease was recorded in Russia in 1912 (15) and at Riazan it was said to be the only serious fungus disease of red clover (21). It has been recorded also as an injurious disease in Slavonia (7) and Hungary (14).

In America *G. caulivorum* was collected by Stewart at Geneva in 1903, and recorded again several years later (39). A note of some inoculation experiments with spores was given by Fulton. The results were positive with *T. hybridum* and *T. pratense*, but negative with *T. repens* and *Medicago sativa* (12). J. Monteith has recently compared the distribution of this species with that of *Colletotrichum Trifolii* in America. *G. caulivorum* is said to occur chiefly in the northern States while *C. Trifolii* is entirely restricted to the southern clover belt—a geographical distribution of species in harmony with the individual responses of the fungi to different temperatures (28).

The systematic position of *Glocosporium caulivorum* Kirchn. has been discussed recently by Karakulin (17), who suggests its transference from the genus *Glocosporium* to that of *Kabatiella*. My own observations show that it is not a typical *Glocosporium*, since it is characterised by a scanty growth of mycelium in the host and on the culture media, the absence of a definite stroma beneath the acervulus, and the short club-shaped conidiophore bearing a terminal crown of conidia. These characters agree with those of the genus *Kabatiella* Bub. as emended by Karakulin (17). The name *Kabatiella caulivora* (Kirchn.) Karak. is therefore adopted.

The fungus shows a very close resemblance to *Polyspora Lini* Lafferty (19), which Karakulin suggests might also belong to *Kabatiella*. The two fungi agree in the manner of conidial

germination, the character of their growth on artificial media, and their method of producing conidia on the host plant. They differ slightly in the shape of the conidia, those of *Polyspora Lini* on flax having a peculiar basal twist which is absent in *Kabatiella*.

Colletotrichum Trifolii Bain.

A preliminary note on a new species of *Colletotrichum* attacking red clover in Tennessee was published in 1905 (1) and the following description of the fungus was given in the next year (2):

Colletotrichum Trifolii Bain: Maculis atris vel fuscis, saepe depressis; acervulis erumpentibus, sparsis vel fusoideis conidiis prope aequalibus; conidiis hyalinis, rectis, utrinque rotundatis, 3–4 × 11–13 μ; setulis cum conidiis, continuis vel uniseptatis, paucis vel numerosis, fuligineis, ad apicem pallidioribus, 4–7 × 39–62 μ, saepe sinuosis vel nodulosis. Habitat in vivis caulibus et petiolis, varissime in foliis *Trifolii pratensis* et *Medicaginis sativae*, Tennessee, Kentucky, Arkansas, Virginia.

The disease is said to be probably the most serious plant disease in the State. The fungus attacks the petioles of yearling plants during the first spells of hot weather and a second period of marked susceptibility occurs about flowering time, when the stems are severely attacked at or slightly below the surface of the ground and also the flowering stems, especially below the flower heads. The fungus attacks *M. sativa* but *T. hybridum* is practically immune.

Experiments were immediately started to obtain a strain of red clover highly resistant or immune to the disease, and ten years later clover anthracnose due to *C. Trifolii* was much less prevalent than in former years, owing in part to the wide use of the resistant strain of red clover produced at the experiment station (4). Melchers, in 1924, states that when heavy damage was done to plots sown with Italian and German seed approximate immunity was found on plots sown with the Tennessee resistant strain (24).

C. Trifolii appears to be confined to the southern States of America and no record of its occurrence in Europe has been found.

Colletotrichum destructivum O'Gara.

A disease of red clover found in the Salt Lake valley, Utah, in 1914 (29, 30) was said to differ from that caused by *C. Trifolii*; the causal organism was regarded as distinct and the following description given:

C. destructivum O'Gara: Maculis indeterminatis brunneis; acervulis minutis 25–71 μ diam., sparsis v. gregariis, erumpentibus, elevatis; mycelio hyalino, granuloso; basidiis fasciculatis, hyalinis cylindraceis v. fusoideis conidiis prope aequalibus; conidiis hyalinis, granulosis, 1–4 guttulatis, rectis v. leniter curvatis,

utrinque rotundatis 3·5–5 × 14–22 μ; setulis inter conidia orientibus, paucis v. numerosis, fuligeneis v. atro-brunneis, sub-rectis v. curvulis, v. flexuosis, saepe nodulosis, continuis, v. obscure 1–septatis, sub-acutis, v. rotundatis, sursum angustioribus, basi 4·5–7 μ crassis, 38–205 μ longis. Hab. in foliis, petiolis caulibusque vivis et languidis *Trifolii pratensis*. Utah, Amer. (30).

There appears to be no further published record of this fungus.

It is evident that knowledge of the anthracnose diseases of clover is at present far from complete. With the exception of drawings of conidia of *G. caulivorum* (18) and photographs of affected stems and leaves, no illustrations have been published of the four species described and few records exist of inoculation experiments. It is hardly surprising, therefore, that more than one author has assumed that the four names are synonymous. Thus it has been suggested that *G. Trifolii* and *G. caulivorum* are merely leaf and stem forms of the same fungus and moreover that they represent the conidial stage of *Pseudopeziza Trifolii* (9, 41). Baudyš adopts this view, and suggests that *C. Trifolii* is another synonym and that anthracnose of clover is actually due to one species only (5). *G. caulivorum* and *C. Trifolii* have again been regarded as synonymous in America (1920) (33, 44).

To elucidate the synonymy and add to the knowledge of this group of diseases it was decided to study the anthracnose disease of red clover which appeared at the Welsh Plant Breeding Station in 1920, of which a preliminary account has already been published (37). The characters of the fungus associated with the disease were found to agree closely with the description of *G. caulivora* Kirchn. Since 1922 it has been possible to compare the fungus with herbarium material and cultures from abroad and to experiment with a culture of *C. Trifolii* from America.

II. *Kabatiella caulivora* (Kirchn.) Karak. (*Gloeosporium caulivorum* Kirchn.)

1. *Symptoms of the disease on red clover and records of its occurrence in England and Wales.*

The attack of *Kabatiella caulivora* on red clover is almost entirely confined to the stems and petioles of the plant. The general effect of an attack in the field is blackened and broken stems, withered petioles and brown, dead leaves. The name "scorch" has been used aptly to describe the disease (42). Plots of badly affected clover present at an early stage of the attack a lighter appearance than plots of healthy clover. This is due to the large number of leaves which, hanging from the wilted leaf stalks, expose their lighter under surfaces. The effect might at first sight be attributed to damage by wind. Leaves thus injured soon wilt, become dry and brown and remain

attached to the plant until mechanically broken (Pl. V). In a moist atmosphere the petioles appear to glisten and examination with a lens reveals the presence of countless minute heaps of hyaline conidia. Occasionally conidiophores also occur sufficiently long to be visible under a powerful lens.

It is not uncommon to find leaves with the attack localised at the pulvini, one or more leaflets hanging down with the blade still green and healthy. The fungus at times spreads from the pulvinus along the mid-rib and in the ground tissue at the base of the blade which may then be covered with acervuli. Actual infections of the blade, independently of the pulvinus, also occur when plants are heavily infected, both in the field and under experimental conditions (see p. 115). Blade lesions are at first dark in colour and the margin of the injured area is clearly defined on both surfaces. In thick leaves the diseased tissues are sunken. Acervuli develop on both surfaces of the lesion when the leaves are kept suitably moist. On the whole such injuries occupy a larger area and are more irregular in shape than those produced by *Pseudopeziza* on the same host. (Pl. VI, figs. 1, 2).

Stem lesions are usually quite characteristic (Pl. VII, fig. 1). The first sign of infection is a small dark spot which spreads chiefly in the longitudinal direction. The blackened cells form an area slightly sunken below the surrounding green healthy tissue. When the diseased area increases the central part becomes lighter in colour and as the stem grows in length and thickness a slit often appears in the centre of the lesion. In dry weather especially, the margins of the slit roll inwards, enlarging the opening, which finally coalesces with the pith cavity present in some stems of red clover. Acervuli are abundant within the pith cavity as well as on the surface of the lesion if the atmosphere is not too dry. The stem is weakened at the seat of attack and not infrequently falls over. If a bend occurs near the base of an otherwise healthy shoot with several branches, these show negative geotropic curvatures, and for a time continue their growth, but eventually the stem may be completely girdled and the death of the whole shoot above the lesion follows. These symptoms recall the "browning" or "stem-break" disease of flax due to *Polyspora Lini*.

On red clover, lesions are often found just below the flower head and the disease then interferes, sometimes very seriously, with seed production. Williams records nearly total loss of seed definitely associated with an attack of this disease (45)*.

* Of two otherwise similar plants of Montgomery red clover growing in direct contact, one suffered from an attack of "scorch" and yielded only thirteen very poorly developed seeds. The other plant was apparently immune and gave 2260 seeds. See also footnote p. 110.

The net result of an attack of "scorch" from the farmer's point of view is a considerably reduced hay crop and weakened plants. Secondary shoots are thrown up by badly affected plants before the first hay crop has been taken and the second cut is thereby reduced even if it escapes an attack of the disease. This feature of the disease was noted by Ware in the south-eastern counties of England in 1923 [cf. Pl. V, fig. 1]. "Scorch" of red clover was first recorded in the British Isles by Petherbridge in 1920 near Cambridge, and in the same year it was reported from Buckinghamshire, Shropshire, Norfolk, Lincolnshire, and Cardiganshire (25), the attack sometimes being very severe. Since then it has been reported in certain parts of Kent, Hampshire, Glamorgan (26), Yorkshire and Derbyshire, but the damage has not been so serious as in 1920. Farm crops of clover were sometimes attacked in the seeding year thus necessitating re-sowing, but generally the attack has attracted attention only in the first harvest year, appearing in both the first and second cuts (25).

2. *Field observations in Wales on the relative resistance of red clover from seed of different origins.*

Several observers have recorded that different "nationalities" of red clover vary in their relative resistance to this disease in the field. Kirchner (18) found in Germany in 1902 that North French red clover suffered more severely than any other and suspected that the fungus might have been introduced by seed from this district. Linhart (20), however, in a more extensive tour of Germany and Bohemia, in the same year, found the fungus widely distributed on both European and American clover. Malkoff (22) recorded a very heavy attack on plots of Italian, South French and North American origin, a slight attack only on those from the west of North America, while lots from Bohemia, South Russia, Poland and Canada were entirely resistant.

In Wales the actual damage sustained by different lots of red clover has varied considerably and the results have shown some consistency from season to season. Data have been collected for four seasons at the Plant Breeding Station on a large number of different samples growing in adjacent rows or plots under similar soil conditions. In 1920, 1921 and 1924 the attack was chiefly studied on clovers in their first harvest year, previous to cutting for the first hay crop, but in 1922 observations were made in September on clovers sown in May of the same year.

In June, 1924, an attempt was made to augment the natural epidemic by spraying the rows with water containing large

numbers of spores of the fungus from several vigorous cultures on oat agar and by establishing "centres of infection" by covering individual inoculated plants for two days with large inverted plant pots. The second method was successful in so far as the covered plants were attacked on almost every stem and leaf, but there was evidence to show that the natural attack would also have been severe at that time.

The data for four years are summarised in Tables I and II. The basis of marking was a maximum of 5 for a plot or row in which every plant was severely attacked. No plot obtained the maximum, but a number of plots in 1920, and a few in 1921 and 1924, received 4 marks.

Table I. Kabatiella caulivora *on red clover from seed of different origin. Marks awarded at the period of maximum attack in the first harvest year in* 1920, 1921 *and* 1924.

Origin of seed	No. of lots, averaged 1924	No. of beds, averaged 1924	Range of marks. Maximum 5	Average marks: 23 June, 1924	13 July*, 1920	7 May*, 1921	Average 3 years
A. *Late flowering group*							
Montgomery	2	6	1·0–2·5	1·7	1·5	1·0	1·4
English late	2	6	1·0–3·0	2·0	1·0	1·0	1·3
Cornish marl	2	6	1·0–3·0	2·2	0·3	0·5	1·0
Foreign late	5	15	1·0–2·0	1·2	—	0·4	0·8
B. *Early flowering group*							
Italian	—	—	—	—	4·0	3·5	3·8
Tennessee selected†	2	6	2·5–4·0	3·1	—	—	3·1
English broad	2	6	1·0–2·5	1·9	3·0	4·0	3·0
Canadian	1	3	3·5–4·0	3·8	2·0	2·0	2·6
Chilian	2	6	2·0–4·0	2·6	3·0	—	2·8
Wild	2	6	1·0–3·0	2·1	—	—	2·1
Brittany	2	6	2·0–3·0	2·3	2·0	2·0	2·1
American early	2	6	1·0–4·0	3·1	1·0	2·0	2·0
Bohemian	—	—	—	—	—	2·0	2·0
Clwyd	2	6	1·0–3·0	1·7	—	—	1·7
Foreign early	—	—	—	—	—	1·3	1·3

* Figures taken from (37), in which further details are given for these years.
† A strain of red clover selected by Bain and Essary (3) for resistance to *Colletotrichum Trifolii*.

The severity of the attack on clover of Italian origin included in the first two trials was very striking (37). Malkoff in Germany (22) and Monteith in America (27) also report on the susceptibility of clover from this source.

A point of special interest in the 1924 data is the severity of the attack on the Tennessee strain which has proved valuable in parts of America on account of its marked resistance to

Colletotrichum Trifolii. Under Welsh conditions this strain appears to be remarkably susceptible to *Kabatiella caulivora* and it would be interesting to know if this be so in America.

Table II. Kabatiella caulivora *on red clover from seed of different origin. Notes made in the seeding year. September 26th, 1922.*

Origin of seed	No. of lots	No. of rows	Average mark. Maximum 5
A. *Late flowering group*			
English late	11	19	1·3
American mammoth	5	5	1·3
Montgomery	14	21	1·0
Swedish late	4	4	0·9
Cornish marl	3	5	0·9
B. *Early flowering group*			
New Zealand	12	12	2·8
Chilian	14	14	2·2
Italian	4	4	1·6
Canadian	5	7	1·5
American early	15	15	1·5
Dorset marl	4	7	1·3
Clwyd	10	14	1·2
European early*	24	35	0·9
English broad	37	76	1·1
Wild	3	5	0·5

* Include seed from Brittany, Bohemia, France, Slovakia, Silesia, Germany, Poland, Switzerland.

The general conclusion is that in Wales, for the conditions prevailing during the seasons under review, the attack of *Kabatiella* was relatively more severe on the early flowering red clovers. Taking the average of three seasons' data, each of the four groups of late flowering clovers showed higher resistance than any of those included among the "earlies," with the possible exception of a few lots of foreign earlies in 1924. It might be suggested that this apparent difference is due to the clovers being necessarily at different growth stages when notes were made, but observations on the late clovers, continued up to the date of cutting, confirm the difference shown some weeks earlier and indicate that in the field these strains suffer less than those which flower earlier in the season.

Among the earlies that from the Vale of Clwyd (Wales) perhaps stands out for resistance, Italian, English broad, Canadian and Chilian for marked susceptibility; wild red, included only in 1924, was attacked moderately heavily*.

In the seeding year (Table II) the difference between the

* The most severe epidemic of "scorch" yet recorded at the Station occurred in June, 1926, on two families of wild red clover which are under genetical study by Mr R. D. Williams. It appears doubtful if any seed will be obtained from one family comprising thirty-four plants.

two groups is not so clearly marked although the most susceptible lots (New Zealand and Chilian) again fall among the early flowering clover. In this experiment, which was not designed for a study of susceptibility to disease, the clovers were sown in drills, grouped roughly according to the source of the seed. The attack in September, 1924, seemed to be spreading from two centres, one among drills of New Zealand and Chilian and the other in late flowering red. If the disease had its origin in one or both of these spots, the adjacent rows would have had the first chance of infection, and time would elapse before the attack could become general. This might account perhaps for the low figure of broad red, compared with the records for this strain obtained in the first harvest year, but it is possible that the relative susceptibility of different clovers varies with the growth stage of the plant.

This experiment was of further interest in showing a severe attack of the disease on clover in the early seedling stage. Some of the rows failed to become established and were re-sown, with the result that in September seedlings with only two or three trifoliate leaves were present, and showed characteristic symptoms of the disease. It is not intended to suggest transmission of the disease by the seed as the seedlings were probably infected by spores from older plants in adjacent drills.

Although within a strain, individual plants of red clover show marked resistance to the disease, an immune plant has not yet been discovered. In 1925, by the kindness of Mr R. D. Williams, I was able to compare under controlled conditions the resistance of two series of propagants of Montgomery red clover, one derived from a plant (No. 801) which was found in 1924 to be very susceptible to *Kabatiella*, and the other from a plant (No. 799) which was practically immune. Well-established plants were inoculated under optimum conditions for infection in a glass-house. Other experiments were made with shoots cut from the plants and retained in jars of water. The experiments are summarised in Table III; while slightly higher percentages of infection were obtained with the propagants from the highly susceptible parent 801, the difference between the two series was very slight and quite unlike that shown under field conditions. The experiment rather suggests that the resistance to this disease shown by clover plants in the field is not comparable with that shown for example by rust immune varieties of wheat, which are found to be immune also under optimum conditions for infection, but recalls rather those varieties which are "rust escaping" under certain field conditions.

Table III. *Infection experiments with propagants from two plants of Montgomery red clover, one noted as susceptible and the other as resistant in the field.*

Details of experiment	Propagants from No. 801 Susceptible 1924		Propagants from No. 799 Resistant 1924	
	No. of inoculations made	Per cent. infections	No. of inoculations made	Per cent. infections
1. Shoots of pot plant inoculated with spores from culture, sprayed with sterile water and kept for two days in moist chambers.	5 flowering stems	100	5 flowering stems	100
2. Similar plants sprayed with suspension of conidia in sterile water.	27 flowering stems	74	24 flowering stems	67
3. Cut shoots at different stages of growth, inoculated as in 1, kept in jars of water in glass-house. (Series of experiments 13 June–8 August.)	57	65	57	53

3. *Morphology of the fungus and its effect on tissues of the host.*

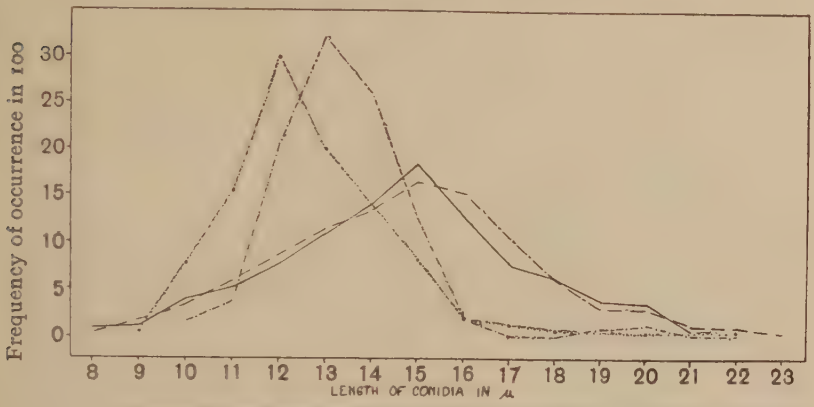
The minute white acervuli occurring on diseased areas consist of short conidiophores, not unlike basidia in shape, growing parallel to each other and pushing through the epidermis, beyond which they do not normally project far (Pl. V, fig. 3). When diseased plants are kept in a moist atmosphere for two or three days, longer conidiophores are produced, extending perhaps 0·1 mm. beyond the epidermis and branching once or twice (Text-fig. II, 3). Conidia are produced from the apex by a process of budding and are usually in groups of three to five, but as many as nine may be found at one time on a single conidiophore (Text-fig. II, 3). The conidia are apparently sessile, but after dispersion very minute papillae may be seen occasionally on the conidiophore.

The conidia when free from the conidiophore are held together to some extent by their mucilaginous walls. The coating of mucilage round each spore may be seen by staining with very dilute gentian violet and mounting in water (6). It was also evident as a transparent layer round spores mounted in prune juice decoction, which is faintly brown in colour.

Mature spores are oblong, slightly bent and tapering at each

end; some are slightly wider at the end remote from the point of attachment. The average measurement is 14·6 × 3·5 μ, the range 8–24 × 2·5–4·5 μ. A frequency curve for the length of conidia is given in the graph below*.

No other spore form has been observed either on the host or in culture, and although a large number of specimens have been examined during a period of six seasons setae have never been found in or near the acervulus. Separate brown setae are however referred to by Karakulin in this fungus (17).



——— – *Kabatiella caulivora* spores from red clover stem (500 measurements)
— – — *Kabatiella caulivora* spores from pure culture (800 measurements)
– · – · – *Colletotrichum Trifolii* spores from red clover stem (500 measurements)
..... *Colletotrichum Trifolii* spores from pure culture (500 measurements)

Graph showing the variation in length of conidia.

A characteristic feature both in culture and on the host is the scanty development of mycelium. The conidiophores arise from coarse septate mycelium running parallel with the epidermis and immediately below it but there is no aggregation of mycelium sufficient to justify the use of the term stroma. The mycelium actually present in diseased tissues is relatively scanty and its presence is to a large extent obscured by the brown material which ultimately fills the attacked cells. The coarse mycelium is mainly found in the intercellular spaces or forcing the cells apart by growth in the middle lamella. On the margin of the diseased area the cell walls are distinctly brown though the contents appear healthy. Some hand sections were on one occasion left overnight in water and then mounted in dilute glycerine and examined again after twenty-four hours. On the extreme margin of the diseased tissue where it had been difficult

* I am indebted to Mr I. G. Lewis for making the measurements upon which the graph is based.

before to observe mycelium and where the only sign of disease was a slight brown discoloration of the cell wall, coarse club-shaped hyphae had grown into the cells from the intercellular spaces, frequently producing there a group of characteristic conidia. The limits of the advancing mycelium were thus clearly marked and it was evident that the first visible sign of the advance was the browning of the cell walls. In advanced lesions hyphae have been seen crossing xylem elements and other cells, but intracellular mycelium is found only where the tissues are completely disorganised.

4. *Isolation of the fungus and proof of its pathogenicity.*

Kabatiella caulivora was first isolated by the present writer in February, 1921, from a petiole of red clover and in the same month the pathogenicity of the fungus in culture was proved by the following experiment.

Conidia from a five-day-old culture on quaker oats agar were placed by means of a sterile platinum needle on the stems and petioles of healthy red clover plants which had been kept for some weeks in a non-heated glass-house and possessed flowering shoots 6–8 inches long. The plants were then sprayed with sterile water and the inoculated shoots enclosed in wide sterile test tubes attached to stakes and plugged at the bottom with cotton wool. Control shoots sprayed with sterile water only were set up before any inoculations were made. After two days the tubes were removed and the plants were kept under observation in a small glass-house containing no other clover plants. The first sign of infection was a dark brown discoloration of one of the inoculated stems, ten days from the date of inoculation. At the end of three weeks, three shoots showed characteristic lesions and the petioles of two leaves were wilted, the leaflets hanging down in a characteristic manner. A week later acervuli were produced and the fungus was re-isolated without difficulty from a stem lesion and from a petiole.

The actual number of inoculations made and the number of successful infections were as follows:

Reference to red clover	Plant organs inoculated	Number of inoculations	Number of infections
Italian No. 63	Internodes of flowering stems 6–9 ins. high.	4	4
Italian No. 63	Petioles	8	2
Italian No. 321	Petioles	6	3

Control stems and petioles remained healthy. The fungus was re-isolated and found to agree with the original culture.

Date of inoculation	Species	Condition of plants inoculated	Method of inoculation	No. of inoculations made	No. of inoculations successful
25. iv. 21	*Trifolium hybridum*	Seedlings 8 weeks old	1	6 petioles	5
10. v. 21	,,	Seedlings 10 weeks old	2	1 pot	2 leaves
22. vi. 26	,,	Seedlings 5 weeks old	2	1 pot	0
19. vii. 21	,,	Plants in bud	1	6 stems	6
18. vii. 21	*T. suaveolens*	Plants nearly in bloom	1	6 stems	5
25. iv. 21	*T. repens*	Seedlings 8 weeks old	1	6 petioles	0
10. v. 21	,,	Seedlings 10 weeks old	2	1 pot	6 leaves
22. vi. 26	,,	Seedlings 5 weeks old	2	1 pot	0
31. v. 21	*T. medium*	Young flowering shoots	1	6 stems	0
19. vii. 21	,,	Plants nearly in bloom	1	5 stems	0
19. vii. 21	*T. incarnatum*	Plants nearly in bloom	1	6 stems	0
22. vi. 26	,,	Seedlings 5 weeks old	2	1 pot	0
25. iv. 21	*Medicago sativa*	Seedlings 8 weeks old	1	12 stems	0
10. v. 21	,,	Seedlings 10 weeks old	2	1 pot	0
22. vi. 26	,,	Seedlings 5 weeks old	2	1 pot	0
19. vii. 21	,,	Plants in bud	1	6 stems	0
25. iv. 21	*M. lupulina*	Seedlings 8 weeks old	1	6 petioles	0
10. v. 21	,,	Seedlings 10 weeks old	2	1 pot	0
22. vi. 26	,,	Seedlings 5 weeks old	2	1 pot	0
12. vii. 21	,,	Plants in bud	1	4 stems	0
12. vii. 21	,,	Plants in bud	1	12 petioles	0
21. vii. 22	*Lathyrus odoratus*	Seedlings 5–6 ins. high	1	12 stems	0
21. vii. 22	,,	Seedlings 5–6 ins. high	1	12 petioles	0
15. vi. 25	,,	Seedlings 5–6 ins. high	1	6 stems	0
15. vi. 25	,,	Seedlings 5–6 ins. high	1	12 petioles	0
19. vii. 21	*Glycine Soja*	Seedlings, stems and petioles	1	6 plants	0
15. vi. 25	*Phaseolus vulgaris*	Plants 5 weeks old, stems and petioles	1	3 plants	0
15. vi. 25	*P. multiflorus*	Plants 5 weeks old, stems and petioles	1	3 plants	0
15. vi. 25	*Vicia Faba*	Plants 5 weeks old, stems and petioles	1	3 plants	0
	*Trifolium pratense**				
25. iv. 21	English late flowering	Seedlings 8 weeks old	1	6	4
25. iv. 21	Wisconsin	Seedlings 8 weeks old	1	6	2
10. v. 21	English late flowering	Seedlings 10 weeks old	2	1 pot	7 leaves
10. v. 21	Wisconsin	Seedlings 10 weeks old	2	1 pot	10 leaves
22. vi. 26	English broad	Seedlings 5 weeks old	2	1 pot	7 leaves†
12. vii. 21	English late flowering	Flowering stems	1	4	4
12. vii. 21	English late flowering	Petioles	1	4	4
12. vii. 21	English broad	Flowering stems	1	4	4
30. v. 22	Italian	Flowering stems	1	6	3
30. v. 22	Italian	Petioles	1	6	3
22. vi. 25	Montgomery	Flowering stems	1	5	5

* Parallel experiments with *T. pratense* to test the pathogenicity of cultures used in the inoculations with other species of Leguminosae. The "source of seed" is given in the species column.

† Two leaves were infected on both petiole and lamina.

It was used successfully in further inoculation experiments with red clover and other species of Leguminosae.

Infection of the blade only was obtained in a later experiment by placing a single drop from a suspension of spores in water on the upper surface of eighteen leaflets. In three a dark spot developed about 1 cm. in diameter and acervuli were finally produced (37). Other blade infections occurred occasionally on red clover plants sprayed with a suspension of spores.

5. *Infection experiments with different species of Leguminosae.*

Kabatiella caulivora has not been recorded under field conditions in Wales on any species other than *Trifolium pratense*. Plants of both alsike and white clover have been carefully examined when growing among or near attacked red clover plants, but they showed no sign of infection. These species, together with *T. suaveolens*, have, however, proved capable of infection when artificially inoculated under controlled conditions. Various experiments, made for the most part in 1921 and 1922, are summarised in Table IV. The pathogenicity of the culture used for a particular experiment was proved by inoculating at the same time and under similar conditions plants of *T. pratense*. The plant organs which were inoculated were not cut or injured in any way. Two methods of inoculation were used and are designated 1 and 2 in the table.

Method 1. Conidia from a fresh culture were spread by means of a sterile platinum needle on the epidermis of certain organs of the plants which had been previously marked by thread or waterproof ink. Sterile water was then sprayed over the whole plant.

Method. 2. Conidia were applied by spraying the plants with a milky suspension of spores in sterile water. Inoculated and control plants, in which sterile water alone was used, were placed separately in suitable moist chambers and retained there for forty-eight hours after inoculation. Positive results were recorded only when characteristic symptoms developed and conidia of *K. caulivora* were produced on the affected areas.

Negative results were obtained with old and young plants of *T. medium*, *T. incarnatum*, *Medicago sativa*, and *M. lupulina*, and with young plants of *Lathyrus odoratus*, *Vicia Faba*, *Glycine Soja*, *Phaseolus multiflorus*, and *P. vulgaris* (Canadian Wonder). *T. pratense*, *T. hybridum*, *T. repens*, and *T. suaveolens* alone proved capable of infection, and in *T. repens* a few leaves in one experiment only were attacked by the fungus.

6. *Germination of the conidia in agar media, in water, and on the epidermis of the host.*

(*a*) *Germination on prune agar*.*

The germination of conidia and the development of colonies from single spores on agar media are illustrated in Text-figs. I, 1–10 and II, 1, 2. The spores were sown very sparsely in films of prune agar† on sterilised cover glasses inverted over a metal ring fastened to a glass slip. The cultures were kept in moist chambers in an incubator at 21° C. The following notes indicate the rate and manner of germination and growth. These data were obtained by the use of spores from a pure culture and confirmed by others taken direct from an affected plant.

Three and one half hours. Distinct increase in size noticed.

Twelve hours. Spores usually dumb-bell-shaped, sometimes with a cross septum already formed (Text-fig. I, 2).

Twenty-four hours. Plantlets of two to fifteen cells of wide diameter. Sometimes a row of three or four cells has been formed and each buds off new conidia. Occasionally each end of a germinating conidium gives rise to a crown of conidia immediately after the development of a cross septum. In others a mycelium of wide barrel-shaped cells is formed and budding is delayed until thirty hours or later (Text-fig. I, 3–6). Any cell of such a plant may finally bud off conidia.

Thirty hours. If budding began early the first-formed cells of the plant are now almost obscured by masses of free conidia (Text-fig. I, 8): if not, the plant consists of coarsely septate mycelium with several branches (Text-fig. I, 7).

Two days. The colonies are now just visible to the naked eye. Their original formation is usually obscured at this stage by the masses of conidia produced. Some of these have already increased in size preparatory to germination.

Three days. The colonies are now too opaque for their structure to be easily discerned. They consist virtually of a mass of conidia sometimes stellate in form, usually oval or circular in outline and lens-shaped (Text-fig. II, 1). Under the microscope the free conidia on the margin of the colony are clearly visible while the centre appears opaque. Microscopically such colonies cannot be distinguished easily in a plate from yeast or bacterial colonies.

Four to five days. This stage is characterised by the germination of free conidia on the margin of the colony. The growth is naturally in the direction of the fresh agar and away from the parent colony. Some typical dumb-bell-shaped spores may be seen on the extreme edge (Text-fig. I, 9). The tendency is for the spores here to form a thinner germ tube and one with fewer septa than when germinating alone with a plentiful supply of nutrients.

Six to seven days. Budding off of conidia now takes place from the mycelium formed by the growth of conidia on the edge of the colony (Text-fig. I, 10).

Petri-dish colonies seven to thirteen days old are about 2 mm. in diameter and consist of a firm central mass already becoming dark in colour with relatively fine mycelium radiating from the margin, 3–5 μ in diameter (Pl. VI, fig. 10). The mycelium is almost entirely submerged, only occasionally in old cultures do a few strands appear above the media. It is rare after thirteen days under these conditions to find newly-formed conidia. If, however, small pieces of the fine marginal mycelium are transferred to fresh agar the cells at once increase in diameter, become closely septate and after two days bud off fresh conidia. This also occurs when the mycelium is transferred to water but the growth is then less vigorous.

* Five prunes per 500 c.c. decoction made up with three per cent. agar.

† These observations are in confirmation of those made by Mr Basil Jenkins (16), who isolated the fungus from red clover and studied it in culture. The writer has pleasure in acknowledging her indebtedness to Mr Jenkins' work.

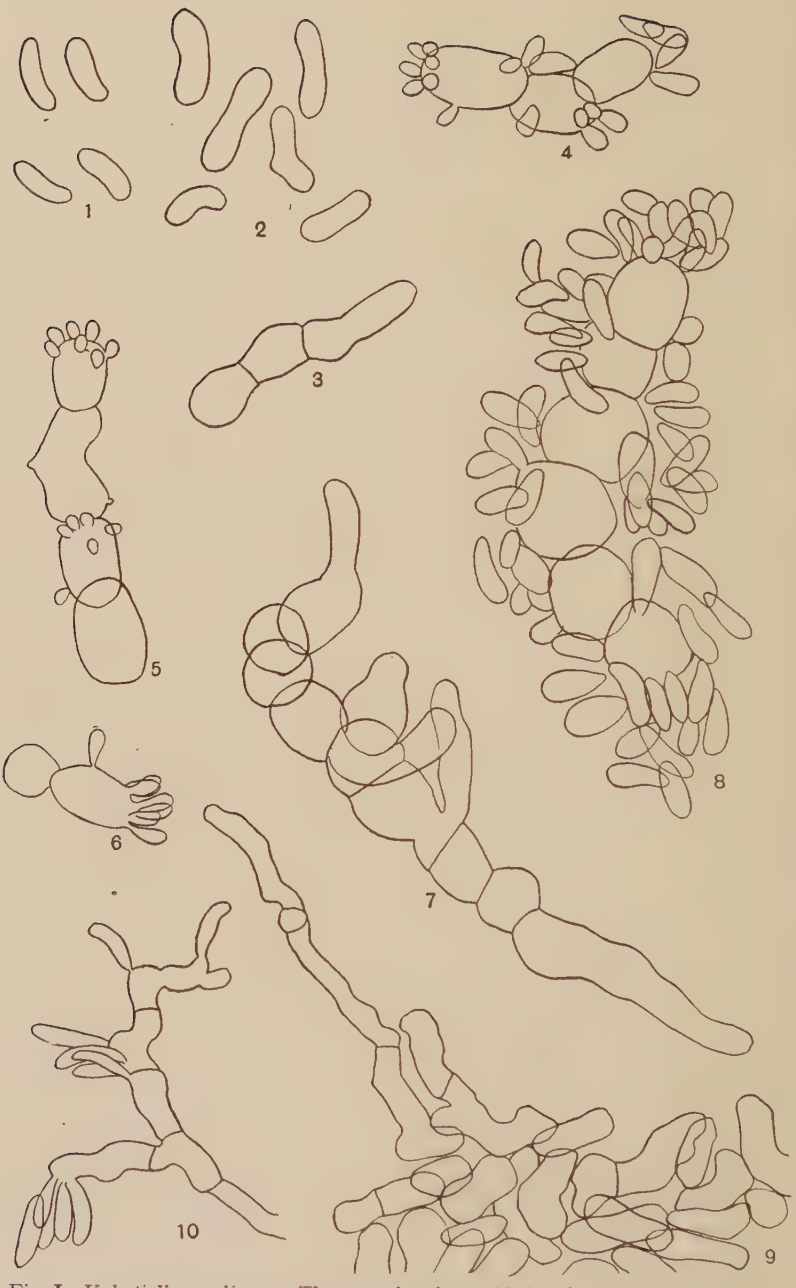


Fig. 1. *Kabatiella caulivora*. The germination and development of conidia on prune agar at 21° C. ×650. 1. Conidia from a pure culture. 2. After twelve hours. 3–6. After twenty-four hours. 7, 8. After thirty hours. 9. After five days; germination of free conidia on the margin of the colony. 10. After seven days; conidia produced on the margin of the colony.

(*b*) *Germination in water.*

Twenty-four hours distilled water (Text-fig. II, 4). The spores elongate considerably and occasionally branch, but rarely form cross septa or bud off conidia.

Fig. II. 1. Colony of *Kabatiella caulivora* on prune agar, forty-eight hours at 21° C. ×500. 2. Production of conidia on the marginal mycelium of colony, four days old, on prune agar. ×290. 3 Group of exceptionally long conidiophores produced on the pulvinus of a leaf of red clover kept for four days in a moist atmosphere at 21° C. ×650. 4–6. Germination of conidia in distilled water (4), water containing a strip of epidermis from a red clover stem (5), and prune agar (6), after twenty-four hours at 21° C. ×650.

Twenty-four hours in distilled water to which a strip of the epidermis from a stem of red clover has been added. The conidia increase in size and bud off conidia from the ends, usually in ones and twos (Text-fig. II, 5). Subsequently long thin germ tubes are formed, sometimes measuring twenty times the length of the spore.

(*c*) *Germination on the surface of the host and invasion of the tissues.*

This was observed first by placing water suspensions of conidia from a fresh agar culture on marked areas of stems of red clover which had been carefully washed in a stream of sterile water. These were kept in Petri dishes lined with moist sterile filter paper at 21° C. The observations were later confirmed by inoculating in the same way some stems of pot plants in a glass-house. Strips of the epidermis were removed at intervals and examined in water under the microscope.

On some stems kept at 21° C. germination had already started after eighteen hours. The spores had increased in size and formed relatively wide germ tubes from one or both ends (Text-fig. III, 1 and 2). After twenty-four hours germination was general and occasionally new conidia were budded off. Sometimes extremely long thin germ tubes were produced as in spores in hanging drops of water containing a strip of epidermis (Text-fig. III, 3).

Penetration of the host cells was observed from the third to the fifth day. The first indication of entrance was a distinct brown colour in the wall of the epidermal cell upon which the spore rested. It was not possible by the method employed to study the penetration of the cuticle but the germ tubes were seen inside the wall which was distinctly swollen at the point of entrance (Text-fig. III, 5, 6). The entering hyphae appeared to travel for some distance in the cell wall immediately below the cuticle and were never seen to penetrate the cell as in *C. Trifolii* described below (p. 133). The protoplasm of epidermal cells thus infected was contracted and slightly discoloured. Text-fig. IV, 1 shows a spore which had formed two germ tubes, each of which was growing in the cell wall below the cuticle. The colourless spore stood out very clearly in this preparation against the brown background of the epidermal cell. The cell walls were distinctly swollen for some distance in front of the germ tubes, as was also the case where advancing hyphae were observed in the host tissues on the margin of an older lesion.

The invasion of the host was studied further by hand sections of very young lesions from stems inoculated from three to five days previously. Such lesions were just visible to the naked eye as minute black flecks on the epidermis. In sections of young lesions, such as that shown in Text-fig. IV, 2, it was only possible to distinguish the epidermal cells after clearing the section with potash solution. Text-fig. IV, 3, 4, 5 were taken from sections which had been cleared with 5 per cent. potash, washed in water and mounted in dilute gentian violet, which showed up the fungus by staining certain granules present in the mycelium. It was evident that the parasite travelled at first only in the

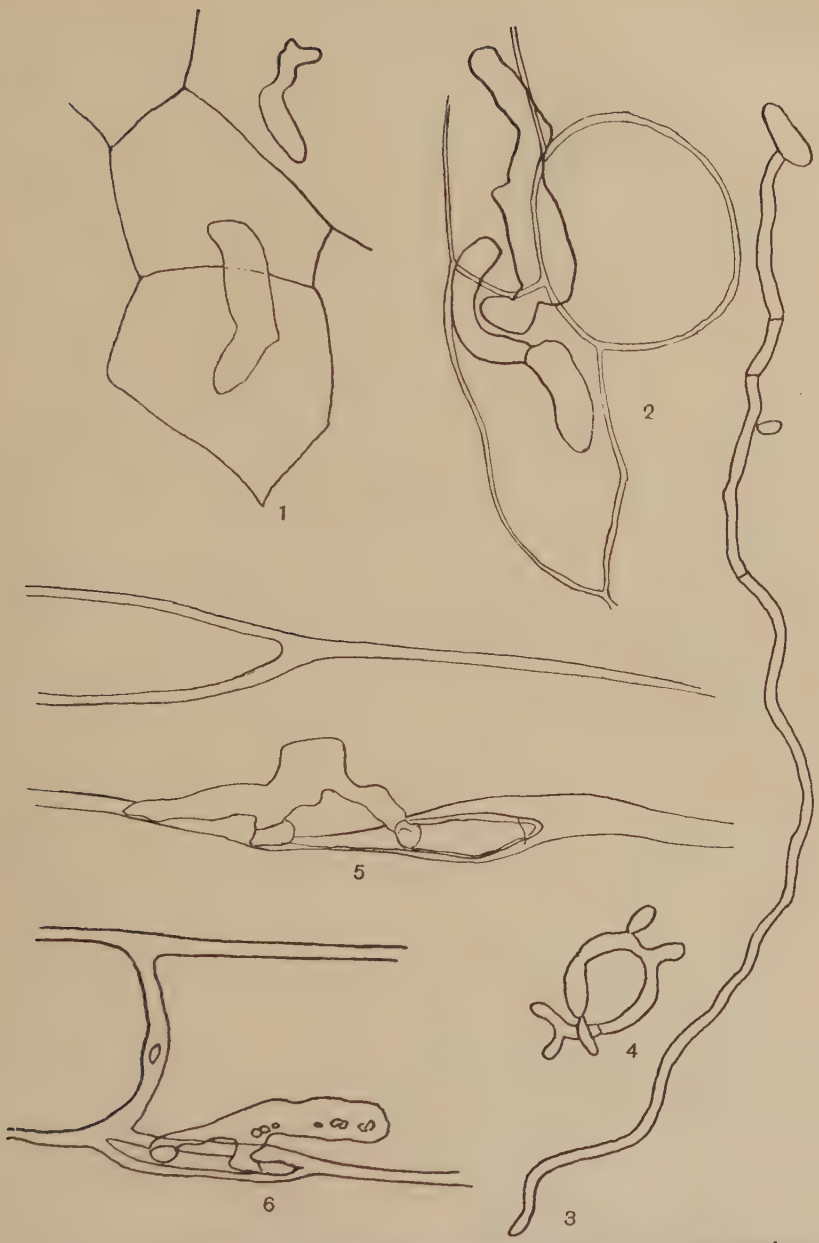


Fig. III. Germination of spores of *Kabatiella caulivora* in water on the surface of red clover stems. 1. After thirty hours at 21° C. ×1300. 2. After forty-eight hours at 21° C. ×1300. 3, 4. After twenty-four hours at 21° C.; large infection drop. ×500. 5, 6. After three to four days at 21° C.; germ tubes penetrating the cell wall. ×580.

Fig. IV. *Kabatiella caulivora* on red clover. 1. Early stage of penetration of the host observed three da after inoculation; germ tubes were seen growing below the cuticle; the cell walls of the host we brown and swollen, and the cell contents were disorganised. ×1300. 2. Transverse section of your lesion on red clover stem; the epidermal cells were obliterated by some brown material, but th lumen became evident when the section was treated with five per cent. potash solution. ×50 3. Transverse section of young lesion cleared with potash; mycelium visible within the ce wall, immediately below the cuticle, was connected with a spore on the surface. ×112 4. Transverse section of older lesion showing mycelium in the swollen cell walls and intercellul spaces. ×1120. 5. Longitudinal section showing mycelium in an intercellular space. ×112 Drawings 3, 4 and 5 were taken from hand sections which had been cleared with potash an mounted in dilute gentian violet. The disorganised contents of the cells are not shown in detail.

cell walls and intercellular spaces, the path of invasion being marked out by a brown discoloration of the cell walls and finally by very dark, almost black, cell contents. The mycelium was scanty and difficult to trace until the tissues were completely disorganised, when coarser strands of mycelium were found from which the conidiophores subsequently developed. *K. caulivora* is thus a marked contrast to *C. Trifolii* which immediately penetrates the lumen of the epidermal cell and forms abundant intracellular mycelium (see p. 133).

7. *Growth on different artificial media.*

The growth of *Kabatiella* has been studied on a large number of different artificial media with the object of inducing the development of other spore forms. It is not necessary to describe all the cultures in detail since the type of growth does not differ very materially on any of the media employed. Prune agar, potato agar, quaker oats agar, and steamed rice have been used most frequently, the last in small conical flasks proving of special value for keeping stock cultures in good condition for long periods with infrequent transfers. The following materials have been used at least once during the experimental period: agar combined with pea meal, bean meal, maize flour, beerwort, potato alone or with five per cent. or ten per cent. cane sugar, oatmeal alone or with two per cent. cane sugar. Cooked potato plugs with or without ten per cent. glycerine*. Cooked stems of *Trifolium pratense, Vicia Faba, Phaseolus multiflorus, P. vulgaris, Epilobium* sp., *Geranium Robertianum, Urtica dioica,* and *Lychnis dioica*; cooked petioles of *Digitalis purpurea, Heracleum Sphondylium, Aegopodium Podagraria,* and *Pteridium aquilinum.* To prepare these, portions of the plants named were placed in test tubes on supports of wet cotton wool and sterilised by steaming for half an hour on three successive days.

K. caulivora made good growth in all the above media. On agar slants or cooked stems kept at 20–22° C. the growth after four days is an opaque cream coloured pasty mass with a smooth glossy surface resembling the growth of certain bacteria. A flesh-coloured tint may develop after about one week, the surface becoming corrugated and dull. Sooner or later, olive-green flecks appear and spread over the culture which becomes very dark, and finally black. The time taken for cultures to turn black depends, among other factors, on the age of the fungus. The interval is shorter when the organism has been for some months in culture. With recent isolations conidia formation is more abundant and extends over a longer period.

* These were prepared according to the method given by Miss Cayley (8).

A sparse white aerial mycelium is sometimes observed in cultures three or more weeks old, especially if the medium becomes dry.

The blackening of the cultures is due mainly to a dark pigment formed in cells of the mycelium and in the germinating conidia, which become compacted together to form a kind of stromatic mass. The dark appearance may be due also to the formation of definite pycnidia. On prune agar these are usually not present before a month or six weeks from the time of transfer but on cooked clover stems they may be found in a fortnight. They are usually small, measuring about 100–120 μ in diameter, but irregular compound pycnidia sometimes develop on agar. Pl. V, fig. 5 shows a pycnidium in section with a central mass of spores. From a study of serial sections it would appear that new pycnidia may develop within the hollow interior of older ones. There was no indication in old or young cultures of ascus formation.

Pycnidia have been recorded on the following media: pea, maize, prune, oat and potato agar; potato plugs with and without glycerine; cooked stems or petioles of *Digitalis purpurea*, *Lychnis dioica*, *Epilobium* sp., *Geranium Robertianum*, and *Trifolium pratense*. They develop both in the presence and absence of light and at 22° C. or at the ordinary temperature of the laboratory in summer and winter*.

8. *Longevity of the conidia and transmission of the disease by contaminated seed.*

The possibility of red clover seed being the source of the disease has been suggested by more than one writer (18, 20, 23), but definite experiments to test this had not previously been made. On June 12th, 1921, the following experiment was started.

A small bulk of Wisconsin red clover seed from which all brown and shrivelled seeds had been carefully separated, was sterilised by soaking for eight minutes in ·1 per cent. mercuric chloride solution, then washed thoroughly in several changes of sterile water and dried between sheets of sterile filter paper. The germination of the sample thus treated was approximately 90 per cent. It was divided into two lots which received the following treatment.

1. *Control.* Seed mixed with sterile water only.
2. *Contaminated.* Seed mixed with sterile water made milky with spores from a pure culture of *K. caulivora*.

Each lot was then dried between sheets of filter paper and the germination again tested. It was not appreciably lowered by the treatment but the bright colour of the seed was lost.

* The pycnidia were usually sterile.

The longevity of the conidia present on the surface of the contaminated sample was studied as follows: About three hundred seeds of each lot were stored in corked specimen tubes in the laboratory and from each a certain number of seeds was examined at intervals over a period of eighteen months. The seeds to be examined were allowed to rest on moist sterile filter paper in covered Petri dishes for five days. The seed coat was then removed and mounted in a drop of water on a microscope slide. At the first test (June 20th, 1921) acervuli of the fungus were evident under a low power lens on the seed coats, and hundreds of spores were present in the water in which the seed coat was mounted. Both acervuli and spores were absent from seeds of the control sample.

The results of five examinations of the contaminated sample are given in Table V. The control sample continued to give negative results. The experiment proves the possibility of viable conidia occurring on the surface of red clover seed eighteen months after harvest.

Table V. *The longevity of conidia of* Kabatiella caulivora *on the surface of red clover seed artificially contaminated.*

Date of test	No. of seeds examined	No. of seeds showing viable conidia*	Per cent. seed showing viable conidia
15. 6.21	10	10	100
15.12.21	20	17	85
22. 2.22	20	9	45
20. 6.22	20	7	35
13.12.22	20	1	5

* As the sample was so heavily contaminated that more than one conidium might be present on a single seed, a positive result was recorded for any particular seed only when conidia were present in large numbers on the slide, indicating that actual budding had taken place.

To discover if contaminated seed produced diseased seedlings one hundred seeds from the two samples, control and contaminated, were sown in boxes of soil on July 7th, 1921, about three weeks after the seed was mixed with spores. As no suitable greenhouse was then available the boxes were placed in the open outside the field laboratory at the farm about a mile from any known diseased red clover. The boxes were protected from birds by wire netting and examined at intervals for symptoms of the disease. On two occasions apparently infected leaves were removed, kept for two days in moist chambers and examined for conidia with the following results:

	Symptoms of disease on		Acervuli present on	
Date of examination	1st leaf	2nd leaf	1st leaf	2nd leaf
August 6th, 1921	1	7	1	6
August 9th, 1921	9	11	9	11

Thus in the box of contaminated seed, one month from the date of sowing, twenty-seven leaves showed symptoms of "scorch" and developed characteristic conidia. Three days later thirty-seven more leaves possessing wilted petioles were counted in this box but they were not examined microscopically. Up to this date not a single seedling in the control box showed signs of the disease.

Both boxes were examined again in September. By this time the disease had spread to the control box which contained four infected plants and forty-eight healthy plants. The other box contained twenty-eight infected plants and only thirteen plants free from infection. The general growth in the control box was estimated by an independent observer as sixty per cent. better than that in the contaminated box.

The experiment affords strong evidence for the transmission of the disease by contaminated seed, but as it was carried out in the open, a further experiment under more carefully controlled conditions was begun in May, 1926. In this experiment *C. Trifolii* was also included (see p. 135).

A small bulk of 1925 seed of English broad red clover was divided into three samples which received the following treatment:

X. Control—Seed shaken with sterile water.

K. K. caulivora—Seed shaken with suspension of spores in sterile water. Spores were taken from a four-day-old culture.

C. C. Trifolii—Seed shaken with suspension of spores from twelve-day-old culture.

Each sample was dried in the laboratory between sheets of sterile filter paper and then stored in clean paper envelopes. On May 27th fifty seeds from each sample were sown in duplicate in pots of soil which had been heated in the autoclave for thirty minutes at 120° C. The pots were placed on a greenhouse bench and pot (1) of each pair was covered with a bell jar. The seed was covered lightly with soil with the anticipated result that the seed coat was frequently carried above the surface on one of the cotyledons. A count, made five days after sowing, gave an average of twenty-four seedlings per pot of which twenty-three had the seed coat still attached.

The first symptoms of disease were observed in pot *K* (1) eighteen days after sowing. Three seedlings showed a brown discoloration of the stalk of one or both cotyledons, the diseased tissue extending also into the base of the cotyledon. After two days' incubation in a moist chamber characteristic acervuli of *K. caulivora* were abundant on the diseased areas (see Pl. VI, fig. 11). Three days later four seedlings with the same symptoms were found in pot *K* (2), which had not been covered by a bell jar.

Four seedlings showed at the same time other symptoms of disease, the cotyledon wilting rapidly. In these, *Botrytis* sp., *Penicillium* sp. and *Macrosporium* sp. were found covering the cotyledon but no spores of *Kabatiella* could be found even after incubation. Three seedlings affected in this way occurred in one of the control pots, on two of them *Penicillium* was found, on the other pycnidia of an unidentified fungus, but out of sixty-eight seedlings which developed in the control pots not one showed the brown lesions characteristic of an attack of *Kabatiella*. From seed contaminated with spores of this fungus seventy seedlings developed and of these seven showed well-defined symptoms and plentiful acervuli. In the pots sown with seed contaminated by spores of *C. Trifolii* sixty-eight seedlings developed, one possessed a shrivelled cotyledon in which pycnidia occurred, while eight were clearly affected by *Colletotrichum* (see p. 135), but there was here no indication of the presence of *Kabatiella*. Thus the experiment confirms the results obtained in the open in 1921, and proves the possibility of contaminated seed giving rise to seedlings affected by the disease. The fungus may develop on the cotyledons or the first true leaves and from such centres of infection the disease might easily spread.

Positive evidence for the transmission of the disease by naturally contaminated seed has not yet been obtained. In June, 1922, duplicate pots of fifty-two samples of red clover seed from twelve different countries were sown in a small greenhouse and the seedlings were carefully examined at intervals for symptoms of disease. Only one seedling in one pot showed any symptoms that could be ascribed to *Kabatiella*, but on incubating the affected leaf, conidia of *Cladosporium* sp. developed.

Seeds from the same samples were examined in the laboratory by Evans (10), who germinated a certain number on agar and isolated the fungi which developed. He recorded species of the following genera: *Penicillium, Stemphyllium, Alternaria, Aspergillus, Botrytis, Mucor, Cladosporium, Fusarium* and two others which produced only sterile mycelium. *Kabatiella* was not recorded although searched for with special care.

There is again no evidence at present for the transmission of the fungus by *infected* seed as in *Polyspora Lini* (19) and *Colletotrichum linicolum* (32) on flax. Further experiments on this point are in progress but, as far as can be gathered from observations already made, the chances of such a method of transmission are small. Flowering shoots infected just below the head usually suffer severely, the stem is quickly girdled with the result that the head droops and withers before any seed is formed. Moreover, the pods in red clover are closely protected by the persistent calyx and corolla and on these the fungus has not yet

been known to occur. Under local conditions the fungus persists during the winter months in the petioles of leaves infected in the late autumn in which the disease develops very slowly*. A careful search in February or March reveals a few petiole lesions from which the fungus may be isolated after a short period of incubation at a higher temperature than prevails in the open. A number of old stems covered with lesions were kept over the winter and examined for resting organs of the fungus, but none were found. The fungus had apparently perished with the cortical layers of the stem, of which little beyond the bleached vascular cylinder tissues was left. Perithecia of *Pleospora* sp. are often abundant on such stems, but there are no grounds for connecting *Kabatiella* with this genus.

III. *Colletotrichum Trifolii* Bain & Essary.

These observations are based on herbarium material on red clover and on a pure culture of the fungus which was used for infection experiments and germination studies.

I am greatly indebted to Mr Monteith, Junior, for this material and for his courtesy in permitting publication.

Apparently *C. Trifolii* has not been recorded in Europe, certainly not in the British Isles, and field observations have therefore not been possible. The object of including the fungus in this study was for comparison with *K. caulivora* since the essential differences between the two species have not been fully described, and the diseases they produce are not universally recognised.

1. *Symptoms of the disease on red clover.*

The general symptoms of *C. Trifolii* on red clover resemble closely those produced by *K. caulivora*. Thus both fungi attack the petioles and stems chiefly and only occasionally cause any spotting of the leaf blades. Affected leaves become brown and shrivelled owing to the collapse and decay of the leaf stalk. Stem lesions are produced by both species with the result that the shoot may fall over at the seat of the injury with the ultimate death of organs above the lesion.

In the absence of the specific organism it might not always be possible to distinguish the two diseases by external symptoms. The chief difference in the early stages of attack lies in the colour of the injured tissue. With *Kabatiella* the invaded cells at once assume an almost black appearance and recently infected stems or petioles show dark spots or long black lines. Older stem lesions have a very dark border surrounding a

* Jenkins(16) found infected petioles bearing acervuli in the open as late as December.

lighter brown centre. In an attack of *C. Trifolii* the first sign of infection is a light brown spot which does not show such a distinct zonation as it increases in size. Furthermore, there is not the same tendency with stem lesions produced by *Colletotrichum* for a slit to develop in the centre of the lesion, a condition characteristic of invasion by *Kabatiella*. When young leaves are attacked *C. Trifolii* rapidly girdles the petiole and the leaf immediately bends at that point. *K. caulivora* tends to grow chiefly in a longitudinal direction forming a long narrow lesion which sometimes extends the length of the petiole and the collapse of the leaf is then more gradual. There is not such a marked colour difference in the case of leaf infections by the two species. Injury to the lamina is apparently rare in *Kabatiella* but less uncommon in an attack of *C. Trifolii*.

When acervuli are present the diseases are quite distinct. If abundant the very minute acervuli of *Kabatiella* give to the lesions the appearance of hoar frost. In *C. Trifolii* the acervuli are somewhat larger and are evident before they burst through the epidermis as minute excrescences. Eventually the lesion is covered with dark spots each of which represents an acervulus with a multitude of black setae among the conidiophores. The conidia themselves if seen in sufficient mass have a very faint pink colour.

2. *Infection experiments and re-isolation of the fungus.*

The culture of *C. Trifolii* from America was received on October 15th, 1925, and an attempt was made at once to infect red clover plants then available. Two pot plants with a few late stems and one seedling plant several weeks old were inoculated by placing conidia on the internodes and petioles. In view of Mr Monteith's work on the temperature relations of this fungus the greenhouse was heated, but it was found impossible to keep the temperature sufficiently high at night. During the period of experiment the range was maximum 64–82° F., minimum 39–58° F. No infection was obtained.

At the same time eight healthy shoots which had not yet flowered were inoculated and placed in jars of water in an incubator at 20–22° C. The outer door was left open but only diffuse daylight could reach the plants. Lesions developed on two stems and typical acervuli and setae were present on the eighth day from the date of inoculation.

Further successful infections in the incubator were obtained in May, 1926, when fresh internodes lying on moist sterile filter paper were inoculated for the purpose of studying the germination of conidia in the epidermis of the host. Typical lesions with characteristic acervuli and setae again developed after eight

days' incubation at 21° C. (Pl. VI, fig. 8). The fungus was re-isolated and the new culture was then used for further infection experiments.

A pot plant of Montgomery red clover was sprayed on June 2nd with a suspension of conidia and placed in a suitable moist chamber for two days. A control plant sprayed with sterile water only was placed in a similar but separate chamber. On the fourteenth day one petiole was shrivelled and bent showing a long brown lesion, on which acervuli of *C. Trifolii* finally developed. The plant possessed three flowering stems and on these four light brown lesions developed with characteristic spores and setae (Pl. VII, fig. 2). The fungus was re-isolated and found to be identical with the original culture. The temperature range during the experiment was 44–96° F.

A second experiment was made on June 17th with two larger plants of red clover of the broad red type. The control plant remained healthy as before while the plant sprayed with a suspension of conidia developed a number of infections on the blades, petioles and pulvini of the leaves and on internodes of the stems. The first symptoms were recorded after ten days and on the thirteenth day from inoculation acervuli were evident on the more advanced lesions. The temperature range during the first ten days was 43–98° F., but a higher humidity was maintained in this than in the previous experiments which might account for the more general infection. The fungus was re-isolated from a lesion on the lamina and again from trefoil in the following experiment.

On June 24th pots of seedlings five weeks old comprising five species of Leguminosae were sprayed with a suspension of spores from a seventeen-day-old culture, enclosed for two days in a moist chamber and afterwards placed on the greenhouse bench. The temperature range during the first week of the experiment was 43–92° F.

The first signs of infection occurred one week from the date of inoculation and four days later the attack was general. The number of seedlings of each species which showed infection is given in Table VI. From the general appearance of the plants *Trifolium incarnatum*, *T. pratense* and *Medicago lupulina* appeared to suffer most severely. The attack was slight on *T. hybridum*, a result which is in agreement with the work of Bain and Essary, who report on the resistance of this species and on the susceptibility of *Medicago sativa* to *C. Trifolii* (3). *M. sativa* seemed at first to be almost free from attack, only two leaves showing definite symptoms of disease, but the inoculated seedlings made poor growth compared with those in the control pot. After three weeks all the seedlings were taken up for

examination in the laboratory and in the case of *M. sativa* characteristic acervuli of the fungus were found on the hypocotyl of forty-two out of forty-three plants examined. The fungus had apparently infected first the cotyledons in an advanced stage of growth when the experiment was started, and from these had attacked the stem, spreading chiefly in a downward direction. Definite lesions were not always present but three of the seedlings were wilting obviously as a result of the injury at ground level. Three plants of *Trifolium incarnatum* and possibly one of *Medicago lupulina* showed the same type of infection, but on *T. pratense* and *T. hybridum* only leaf infections were found*.

It is evident that *C. Trifolii* has a wider range of host species than *K. caulivora*, which, in a parallel experiment, infected only red clover (see p. 116) and has in a number of other experiments failed to infect *T. incarnatum*, *M. lupulina* and *M. sativa*.

Table VI. *Infection experiments with* Colletotrichum Trifolii *isolated from* Trifolium pratense.

Species	No. of seedlings inoculated	No. of seedlings with one or more leaves infected	No. of leaves with lesions on the blade	No. of seedlings infected at the hypocotyl
Trifolium pratense (English broad)	16	12	4	0
Trifolium pratense (English late)	10	9	3	0
Medicago lupulina	14	8	2	1
T. incarnatum	22	18	6	3
M. sativa	43	2	0	42
T. hybridum	45	9	1	0

3. *Germination of the conidia in nutrient media and on the epidermis of the host.*

(*a*) *Conidia sown in a hanging drop culture of prune juice at* 21° C.

Twelve hours. Conidia had increased considerably in size and produced short germ tubes from one or both ends.

Twenty-four hours. Some spores had now divided across the middle by a septum, or one germ tube was considerably longer than the other and separated from the spore by a cross-wall (Text-fig. V, 2–4).

Thirty-six hours. Elongation and branching of the germ tubes (Text-fig. V, 5).

Two days. Circular plant about 0·8 mm. in diameter consisting of branched hyphae radiating from a centre which marks the position of the spore (Text-fig. V, 6).

* Since making this report a further infection experiment was made with *C. Trifolii* in which *Trifolium medium*, *T. pratense*, *T. repens*, and *M. lupulina* were included. Single well-developed pot plants, eight weeks old, were inoculated. *T. pratense* and *M. lupulina* (one plant each) showed fifty and forty-two per cent. of infected leaves respectively, but *T. repens* (two plants) and *T. medium* (five plants) gave negative results.

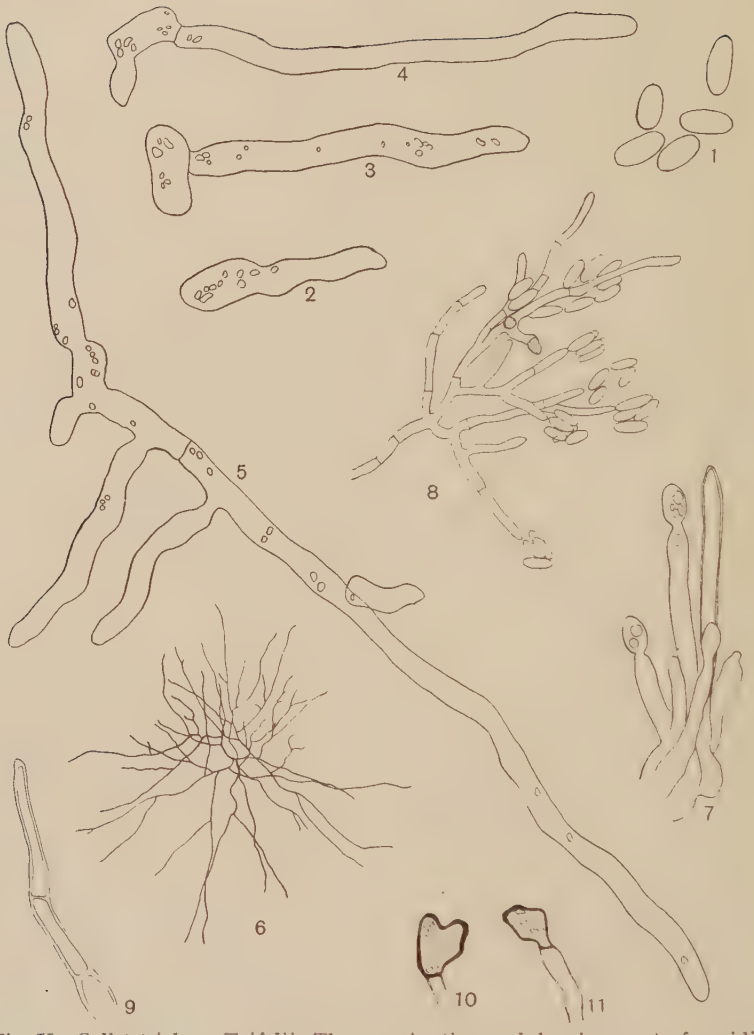


Fig. V. *Colletotrichum Trifolii*. The germination and development of conidia. 1. Conidia from a pure culture. ×650. 2–4. After twenty-four hours on prune agar at 21° C. ×650. 5. After thirty-six hours on prune agar at 21° C. ×650. 6. Growth in prune juice medium, two days at 21° C. ×55. 7. Conidiophores and seta produced after three days at 21° C. in a sowing of conidia in prune juice medium on a red clover stem. ×650. 8. Young acervulus with appressoria from a pure culture. ×250. 9. Seta from a culture. ×650. 10, 11. Appressoria produced in culture. ×650.

Three days. Development of numerous short branches in clusters. Cross or clamp connections between the branches occur. Some large spherical cells were noticed containing highly vacuolated protoplasm. Setae and an occasional conidiophore were evident among the short branches which appear to indicate the point of origin of an acervulus.

Four days. Further developments of setae and the production of large numbers of free conidia. An olive-green pigment is now evident in the oldest mycelium.

In water the initial stages of germination occur and correspond to those recorded for prune juice medium. The sequence of development is also essentially the same in agar media. Pl. VII, fig. 7 shows colonies of *C. Trifolii* one week old on a prune-agar plate culture. Well-developed acervuli were present.

Appressoria. In slant cultures of *C. Trifolii* hyphae which come into contact with the sides of the test tube frequently develop at their tips dark brown irregularly shaped cells, possessing thick walls, in which one or more minute pores are visible (Text-fig. V, 10, 11). These cells are exactly similar to the appressoria described by Pethybridge and Lafferty for *C. linicolum* (32) but in the clover fungus they were not observed to occur in chains. The development of appressoria on the host is described below.

(*b*) *Germination of conidia on the surface of red clover stems and penetration of the epidermal cells.*

The germination of conidia on the surface of the host was studied by placing suspensions of conidia on marked areas of cut stems contained in moist chambers and incubated at 21° C.

Spores from a pure culture were sown in drops of sterile water or in dilute prune juice medium and the sequence of development was similar in both media. In prune juice, however, especially if the infection drop were large, germination proceeded until a considerable mass of mycelium had developed and sometimes even setae and conidia (three days) (Text-fig. V, 7). Penetration of the epidermis was not observed.

In a film of water on the surface of a clover stem germination usually occurs at one end of the spore; a very short germ tube appears and at once swells at the tip to form a spherical appressorium which is often immediately adjacent to the spore, though sometimes separated from it by a short narrow hypha from which a branch may later arise (Text-fig. VI, 4). Fully developed appressoria were numerous after forty-eight hours at 21° C.

The protoplasmic contents of the conidium pass over into the appressorium and it is from this cell that the penetrating hypha arises. Text-fig. VI, 7 was drawn in three different planes. The faint walls of the empty conidium and the hypha connecting it with the appressorium were distinctly seen in the first plane. The outline of the appressorium was drawn at a slightly lower focus and finally within the epidermal cell two hyphae could be seen with very fine granular contents. The

penetrating hypha had clearly entered the cell at a point where the appressorium rested on the epidermal cell and had immediately divided, a branch growing towards each end of the host

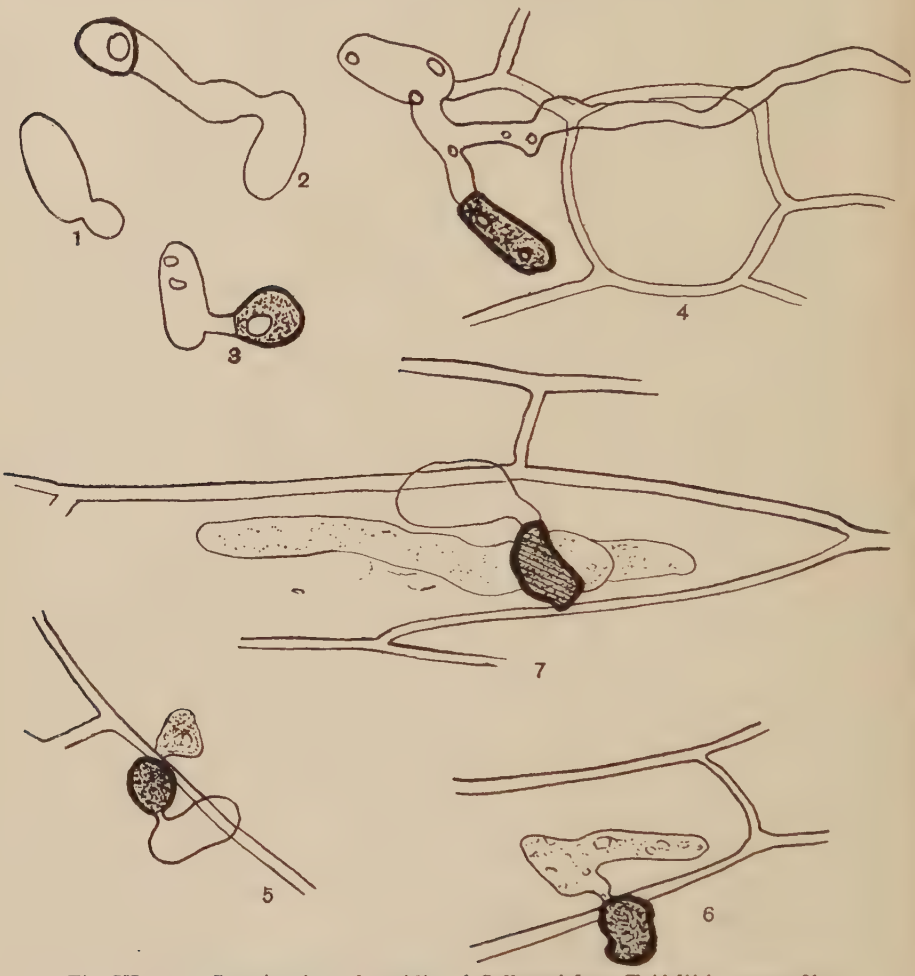


Fig. VI. 1–4. Germination of conidia of *Colletotrichum Trifolii* in water films on the surface of a red clover stem showing the development of appressoria. ×1300. 5–7. Penetration of epidermal cells by hyphae from appressoria. ×1300.

cell. The wall of the cell was not discoloured as in penetration by *K. caulivora* (p. 120) but the contents were faintly brown and there was a distinct contraction of the protoplasm. On the same strip of epidermis a more advanced stage of penetration was

observed in which the epidermal cells were filled with coarse, vacuolated mycelium. Branching could be seen within the cell and the passage of hyphae through cell walls could be traced. The hyphae were much constricted at the point of penetration and swollen on either side of the cell wall.

The host cells were distinctly brown where penetrated by a branch of mycelium but there was here little visible evidence of "action in advance," cells not penetrated being apparently healthy.

4. *Growth on different artificial media.*

C. Trifolii has been grown in pure culture on the following media: prune, bean meal and plain potato agar; potato agar with five per cent. and ten per cent. cane sugar; cooked potato plugs with and without glycerine, steamed rice and cooked stems of red clover. Growth was good on all media tested consisting at first of colourless submerged mycelium which finally turned black and upon which salmon pink coloured acervuli developed. In Pl. VI, fig. 12 the central flask contained cooked rice covered with four weeks' old growth of *C. Trifolii* with abundant acervuli. The left and right flasks contained similar cultures of *K. caulivora*, the first isolated from red clover in Wales, the second received from America. A dark pigment was only just beginning to develop in the cultures of *Kabatiella* which continues for several weeks to produce masses of conidia on rice and remains pink for a long time on this medium.

The dark pigment in the mycelium and the pink colour of the acervuli of *C. Trifolii* developed in the presence and absence of light and at temperatures ranging from 15–23° C. Higher and lower temperatures were not tested.

Setae are abundant in culture and contribute to the blackening of the cultures. They are very variable in size, ranging from 33–110 μ in length.

5. *Transmission of the disease by contaminated seed.*

Seed of red clover artificially contaminated with spores of *C. Trifolii* was included in an experiment with *K. caulivora* the details of which have been given already (p. 126). Eight seedlings out of sixty-eight raised from contaminated seed were attacked by *Colletotrichum* which was altogether absent from the control pots and from those in which *K. caulivora* developed. The infected seedlings showed lesions on one or both cotyledons and on the hypocotyl (Pl. VI, fig. 9). On the diseased area acervuli developed, the setae being particularly conspicuous. Here, invasion of the cotyledons started at the side while that of *Kabatiella* began always at the stalk end, and progressed more slowly, but such a distinction may not be constant.

The experiment indicates the possibility of contaminated seed serving as a carrier of the disease. No information is available on transmission by infected seed.

IV. Examination of Specimens and Cultures from other Countries.

1. *Kabatiella caulivora* (Kirchn.) Karak. (*Gloeosporium caulivorum* Kirchn.).

In 1922, by the kindness of M. T. A. C. Schoevers, Wageningen, pickled material of red clover attacked by this fungus was received. The symptoms were identical with those observed in Wales and measurements of conidia agreed also with those made in this locality. In the same year a culture was obtained from Dr Johanne Westerdijk, Central Bureau voor Schimmelculturen, Baarn, Holland, and compared with isolations made from Welsh material. The agreement was close allowing for the fact that the Dutch fungus had evidently been in culture for some time. Successful inoculations were made with the Dutch culture on stems and petioles of red clover and typical symptoms of "scorch" disease were produced. The Dutch strain was not tested on other species of Leguminosae.

In October, 1925, a culture of *K. caulivora* was received from America and compared with the Welsh strain. No differences in cultural characteristics were observed except a tendency for sub-cultures of the American strain to develop the dark pigment earlier than the Welsh strain. This character may possibly be related to the age of the culture. Herbarium specimens showing conidia on stems and petioles have also been received from America.

2. *Colletotrichum Trifolii* Bain & Essary.

In addition to the American material which has already been described a culture of this fungus was received with the previous species from Holland. The mycelial characters and general growth of the fungus agreed with that from America, but no medium would induce spore formation, and inoculation experiments with mycelium gave negative results.

3. *Gloeosporium Trifolii* Peck.

I am indebted to Dr James R. Weir, formerly Pathologist in charge of pathological collections, Bureau of Plant Industry, Washington, for the privilege of examining part of the type material of this and the following species, and to Dr E. A. Jorgensen, Head of the Botanical Department, Statens Plantepatologiske Forsøg, Botanisk Afdeling, Lyngby, for two Danish

collections of *G. Trifolii* on red clover. Unfortunately no spores could be found on the dry material but from the general symptoms the disease appears to be distinct from any type of leaf injury I have met with on red clover in this country. Photographs of the herbarium material of *G. Trifolii* are shown in Pl. VII, figs. 5, 6, in comparison with lesions produced by two other species of fungi. The closest resemblance is perhaps with the "spotting" caused by *Pseudopeziza Trifolii*, but the lesions produced by the *Gloeosporium* are more irregular in shape and more sharply outlined than those due to *Pseudopeziza*. Until fresh collections of material are available nothing more can be said as to the origin of this type of leaf spot, but it seems improbable that it is in any way connected with either *Kabatiella caulivora* or *C. Trifolii* which only infrequently attack the blade. Professor F. R. Jones referred in a letter to *G. Trifolii* as the "cause of a minor leaf spot" which he had not seen in America for several years and he stated also that he had never been able to induce the spores to germinate.

4. *Colletotrichum destructivum* O'Gara.

On the single leaf which was available for examination no spores or setae could be found and the writer was unable therefore to compare this species with *C. Trifolii*. From the diagnosis given (p. 105) the differences between the two species appear to be slight.

The experiments here recorded have been carried out at the Welsh Plant Breeding Station and I wish to record my thanks to Professor Stapledon, M.A., for granting facilities and for his constant interest in the work.

I am greatly indebted to Mr R. D. Williams, M.Sc., for various seed samples and plants and for his valuable help in matters relating to varieties of red clover. Thanks are given also to Mr Watkins for his careful supervision of cultural details.

Special thanks are accorded to Mr Cotton, Dr Butler and to Professor F. R. Jones for valuable assistance with literature and to Miss Rhoda Jones for translations of foreign papers.

Finally the writer wishes to thank all from whom cultures and specimens have been received, to whom reference has been made already, and in addition other workers who have kindly replied to enquiries made in connection with these studies.

Summary.

The paper deals with two of four fungi which have been recorded as the cause of anthracnose diseases of red clover.

1. ***Kabatiella caulivora*** (Kirchn.) Karak. (***Gloeosporium caulivorum*** Kirchn.).

This fungus is widely distributed, occurring in various European countries and in the northern states of America. It has been recorded in eleven counties in England and Wales. Petioles, stems, and occasionally the blades of red clover are attacked, with the formation of characteristic lesions. On the stem these are dark brown to black with a lighter centre which may become hollow. The general result is one of shrivelled leaves and broken stems. The fungus is characterised by minute hyaline acervuli each consisting of a cluster of basidia-like conidiophores projecting only a short distance from the epidermis and bearing terminally a group of non-septate sickle-shaped conidia. Single spore isolations have been made and the pathogenicity of the fungus proved.

The germination of conidia on artificial media is characterised by the early and repeated budding off of conidia and by the scanty development of mycelium. Growth on media resembles at first a bacterial streak. Later it becomes black and small pycnidia are developed.

On the host the spore sends out a slender germ tube which grows at first in the cell wall immediately below the cuticle. Growth in the host is preceded by brown discoloration of the cell walls and eventually the cells have brown contents. The mycelium is almost entirely intercellular.

In the field, late flowering clovers were found on the whole to be more resistant than the early flowering strains. *Trifolium hybridum* and *T. repens* have been infected experimentally, but *T. incarnatum*, *Medicago lupulina*, *M. sativa* and several other members of the Leguminosae appear to be immune.

Seed artificially contaminated with the spores of the fungus gave rise to diseased seedlings, the fungus developing on the cotyledons and first leaves.

2. ***Colletotrichum Trifolii*** Bain & Essary.

This species has not yet been reported outside the southern states of North America.

The disease has been studied by inoculating red clover plants with spores from a pure culture received from America. Stems and petioles are attacked and the lesions are usually lighter in colour and do not develop a hollow centre like those produced by the previous fungus.

Mycelium is plentiful in cells of the cortex, pith, and thin walled cells of the vascular bundles. It is largely intracellular.

Acervuli are accompanied by numerous black setae. The

spores are straight, cylindrical and produced singly on slender conidiophores which arise from a slight stroma. Germinating on nutrient media the conidia form bipolar germ tubes which branch and give rise to a circular growth of mycelium. This develops a dark pigment and on it arise pink acervuli of conidia and setae like those produced on the host. Appressoria are developed in culture and on the host immediately the spores germinate.

Seedlings raised from seed contaminated with spores from a culture developed after three weeks the disease on hypocotyl and cotyledons.

In addition to *Trifolium pratense* the disease has been produced on *Trifolium incarnatum*, *Medicago lupulina*, *M. sativa* and *T. hybridum*, the latter species showing most resistance. *T. repens* and *T. medium* (one experiment) gave negative results.

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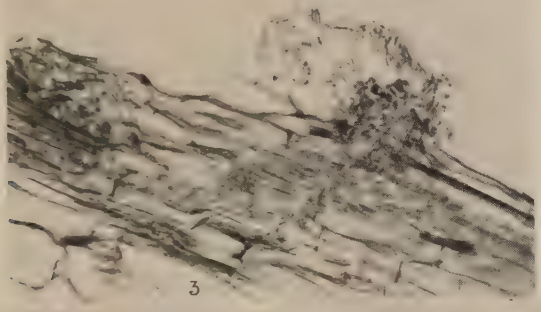
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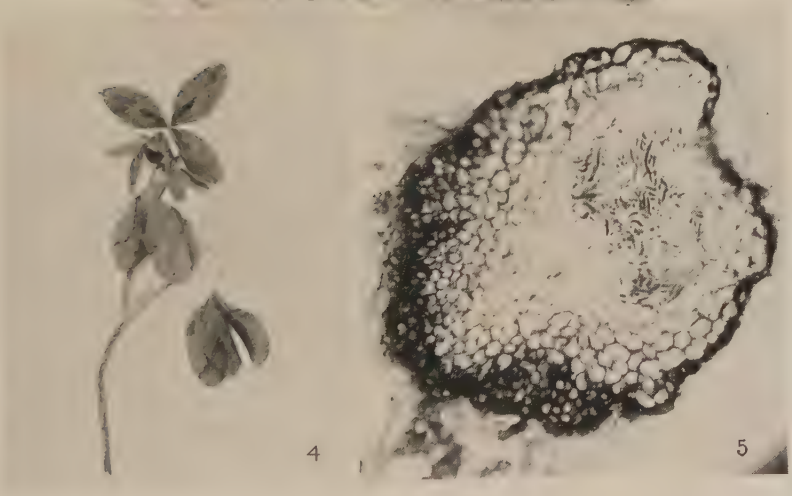
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EXPLANATION OF PLATES.

Plate V.

Figs. 1, 2. Plants of red clover attacked by *Kabatiella caulivora*. (In fig. 1 premature secondary growth has developed.)
Fig. 3. Acervulus of *K. caulivora* on red clover stem from microtomed longitudinal section stained with Delafield's haematoxylin.
Fig. 4. Flowering shoot of red clover showing petiole and stem lesions caused by the same fungus.
Fig. 5. Longitudinal section of pycnidium from culture on prune agar.

Plate VI.

Figs. 1, 2. *K. caulivora*. In fig. 1 the pulvinus of a leaflet is affected and the advance of the fungus into the leaf is indicated by a characteristic discoloration of the veins.
Figs. 3, 4. *Colletotrichum Trifolii* Bain & Essary on crimson clover.
Figs. 5, 6. *C. Trifolii* Bain & Essary on trefoil.
Fig. 7. *C. Trifolii* Bain & Essary on red clover.
Fig. 8. Stem lesion on red clover caused by *C. Trifolii* developed under moist conditions in an incubator.
Fig. 9. Seedling of red clover derived from seed contaminated with spores of *C. Trifolii*, showing one cotyledon attacked by the fungus.
Fig. 10. Seven-day-old colonies of *K. caulivora* on prune agar.
Fig. 11. Seedlings of red clover showing symptoms of "scorch" on the cotyledons, obtained by sowing contaminated seed.
Fig. 12. Cultures (1 month old) of *C. Trifolii* (flask 1) and *K. caulivora* (flasks 2, 3).
Fig. 13. Acervulus with setae of *C. Trifolii* on red clover stem from microtomed section stained with eosin.

Plate VII.

Fig. 1. Stem lesions on red clover caused by *Kabatiella caulivora*. (*a*) Early stage. (*b*) More advanced stage. A slit has developed and the pith cavity is exposed. (*c*) Lesions with a characteristic dark border and a lighter coloured centre on which acervuli have developed.
Fig. 2. Stem lesion on red clover caused by *Colletotrichum Trifolii* produced by inoculation on a pot plant and developed under relatively dry conditions in a greenhouse.
Fig. 3. Injury on red clover leaf due to *Mycosphaerella carinthiaca* Jaap.
Fig. 4. Injury on red clover leaf due to *Pseudopeziza Trifolii* Fckl.
Figs. 5, 6. *Gloeosporium Trifolii* Peck. Upper and lower surfaces respectively of two leaflets from type material ex U.S.A.
Fig. 7. Seven-day-old colonies of *C. Trifolii* on prune agar, with well-developed acervuli.
Fig. 8. *G. Trifolii* Peck. Danish material.

NOTE.

After this paper was written an important paper by S. J. Wellensiek* appeared dealing chiefly with cultural characteristics of *Kabatiella caulivora*, its thermal relations and method of hibernation, and with infection experiments, which indicate the range of susceptibility in different forms of *Trifolium pratense*, and other species of Leguminosae.

It is evident that the cultural characteristics of the Dutch

* Waarnemingen over de Klaverstengelbrandziekte (Observations on clover anthracnose). *Tijdschrift over Plantenziekten*, XXXII (1926), 266–302.

strain of *K. caulivora* are not identical with those of the strain studied in Wales which is remarkable for the scanty growth of mycelium produced on all cultural media. The strains differ also in their capacity for developing mature pycnidia in culture. The Welsh strain forms small black bodies on various media, but I have only occasionally found conidia in them and have so far failed to observe the extrusion of ripe spores. The fertile pycnidium shown on Pl. V, fig. 5 was discovered in old material after reading Wellensiek's paper.

In view of these cultural differences it is interesting to find that infection experiments with the two strains gave very similar results. In both countries *T. pratense* was undoubtedly the most susceptible species, while *T. hybridum* and *T. repens* showed slight infection. On the other hand certain varieties of *T. incarnatum* and *Medicago lupulina* (as full grown plants only) were susceptible in Holland but immune in Wales. This discrepancy might possibly be due to differences in the variety or in the growth stage of the host plant employed in the two investigations.

Wellensiek's observations on the occurrence of a perennial mycelium in the basal leaves of the plant agree with mine (37). He failed, however, to obtain evidence of transmission of the disease by the seed even under experimental conditions. He found that *K. caulivora* will grow in culture on several types of soil, resisting low temperatures and causing severe infection on seedlings raised in artificially contaminated soil.

NOTES.

MUTINUS BAMBUSINUS (ZOLL.) ED. FISCHER.

As illustrated in the *Transactions of the British Mycological Society*, vol. x, Plate XIV, the head of *Mutinus bambusinus* is usually crimson. In May 1926, a large growth of this species was observed in a bamboo clump at Kandy, Ceylon, consisting of several hundred specimens, in none of which was there any trace of red. The head was olive brown when bearing the gleba, and hyaline to dirty white when the gleba was washed off.

T. PETCH.

BROWN THREAD BLIGHT.

In the *Annals of the Royal Botanic Gardens, Peradeniya*, vol. x, p. 35 (1924), I described a Brown Thread Blight from West Africa where it had been collected on cacao and kola by Mr R. H. Bunting. The description was as follows:

"The thread occurs on the stems and leaves. On the latter it branches at a fairly wide angle and spreads out over the leaf,

sometimes extending over nearly the whole of a cacao leaf. In one gathering, the thread is on the upper side of the leaf, but in the other two it is on the lower side."

"The thread is tawny brown, slightly longitudinally fibrillose. It is not bordered by a white film, as in the corresponding Ceylon species. The hyphae are yellow-brown, 2–4 μ diameter, of the usual Thread Blight shape, but with walls only moderately thickened. Septa are frequent, and many hyphae show normal branching, the lateral branch arising just below a septum. Hyphae which spread out from the cord over the leaf tend to fork and form expansions at their extremities, but this is not as well-marked as in the parallel Ceylon form. Fine hyphae have not been observed. The yellow-brown hyphae do not stain with eosin.

"One example bears immature pilei, and fragments of mature pilei, attached to the thread. The immature pilei are small pezizoid structures, cup-shaped, 0·2 mm. high, 0·3 mm. diameter, white pruinose externally. The fragments are strongly brownish white pruinose externally with a red-brown hymenial layer. The outer (upper) surface bears irregular hyphae, 4 μ diameter, rough with projecting points or elongated spines, or bearing short bristle-like appendages, and encrusted with calcium oxalate.

"It is probable from the specimens available that the fructification of this species is a Marasmius."

In 1925, Mr Bunting kindly sent me further specimens of this thread blight, in this instance bearing the fructifications of the fungus. As surmised, these proved to be a *Marasmius*, which may be known as *Marasmius byssicola*.

Marasmius byssicola Petch, n.sp. Pileus reniform or orbicular, up to 1·5 mm. diameter, feebly convex, brownish-white, strongly pruinose, not sulcate, clothed with branching hyphae, up to 4 μ diameter, which bear numerous clavate tips and are rough with projecting or elongated spines and encrusted with calcium oxalate: stalk excentric, almost lateral, black or blackish brown, fibrillose, about 0·25 mm. long, 0·5 mm. diameter: gills usually three, adnate, sometimes forked, sometimes with shorter intermediate gills, ventricose on the larger examples: spores not seen: mycelium superficial, over-running the host plant in tawny brown, longitudinally fibrillose strands or expanding in thin brown films: pilei produced on the strands or films, or independently from the decayed host tissue. Parasitic on cacao (*Theobroma Cacao* L.) and kola (*Cola acuminata* Schott & Endl.), West Africa.

On these later specimens, the hymenium is pale ochraceous. Apparently it becomes red-brown only when old. T. PETCH.

REVIEW.

Principles of Soil Microbiology. By SELMAN A. WAKSMAN. Baillière, Tindall and Cox: London. 1927. pp. xxviii + 897. Price 45*s*.

This book of nearly nine hundred pages hails from the United States of America and is dedicated to the two pioneers, Beijerinck and Winogradsky, both now in their seventies. It is divided into four main parts of unequal length which deal, in a total of thirty-two chapters, with the occurrence and differentiation of microorganisms in the soil, their isolation, identification and cultivation, their chemical activities and with soil microbiological processes and soil fertility.

The book is frankly a compilation and covers a great deal of ground. The author has wisely availed himself of the services of various specialists, in his own and in other countries, for reading and criticising many of the chapters, and presumably he has profited thereby. In spite of this, however, there are occasional slips such as on p. 236 where the potato Wart Disease producing organism (*Synchytrium endobioticum*) is reckoned amongst the Myxomycetes and on p. 276 where *Rhizoctonia* is said to belong to the Ascomycetes. It may be noted here, also, that proof-reading has been by no means perfect, for typographical errors occur more frequently than they should.

The author himself has paid special attention to soil Actinomycetes and has published several memoirs on the subject. Plant pathologists, and especially those interested in the Scab diseases of potatoes and other crops, will therefore welcome the account given of these organisms in chapter XII. On p. 292 it is stated that "The term colony is used incorrectly in designating a mass of growth of an actinomyces, since it is merely a mass of mycelium developing out of a single spore, and not a colony in the sense of bacterial growth." This is perfectly true, and deserves the attention of mycologists in connection with groups of organisms other than the Actinomycetes.

In dealing with the effects resulting from partial soil sterilisation it is satisfactory to find that the "protozoan theory of soil fertility"—about which so much has been heard in this country that one began to wonder whether its sponsors had not deluded themselves into believing that it was something more than a theory—takes its proper place in the ranks along with other theories that have been advanced to explain the facts, none of which, however, appears to be quite adequate.

In the section (p. 806) dealing with plant diseases caused by fungi found in the soil, after mentioning *Fusarium radicicola* and *Rhizoctonia S. ani* it is stated that *Phytophthora infestans* can live saprophytically in the soil on old partially decomposed plants, and the work of Miss de Bruyn in Holland is cited. Such a statement is apt to be misleading, for the reader might suppose that the organism causing the potato blight is a more or less common soil inhabitant. It needs to be emphasised that the work was done with cultures of the fungus in *sterilised* soil, and it was assumed that there was no difference in the behaviour of the fungus towards sterilised and unsterilised soil, an assumption which many will think totally unwarranted.

The last chapter of the book is devoted to the history of soil microbiology, its past, present and future, and is, perhaps, a little disappointing; for, after a while, it becomes not much more than a catalogue of names and dates; in a mere nine pages, however, it was scarcely possible to develop the story more adequately.

The book as a whole may be regarded as a serious and praiseworthy attempt to survey a very wide field; and although not without certain defects it will doubtless be found of considerable value by students and research workers. Every page is provided with footnotes referring to the relevant literature, which, as is well known, is widely distributed in a multitude of publications. Furthermore, a twenty page index of authors is supplied at the end. The book is, in fact, an up-to-date summing up of the vast amount of literature on the subject of soil microorganisms and as such will be found of very considerable value for reference purposes.

G. H. P.